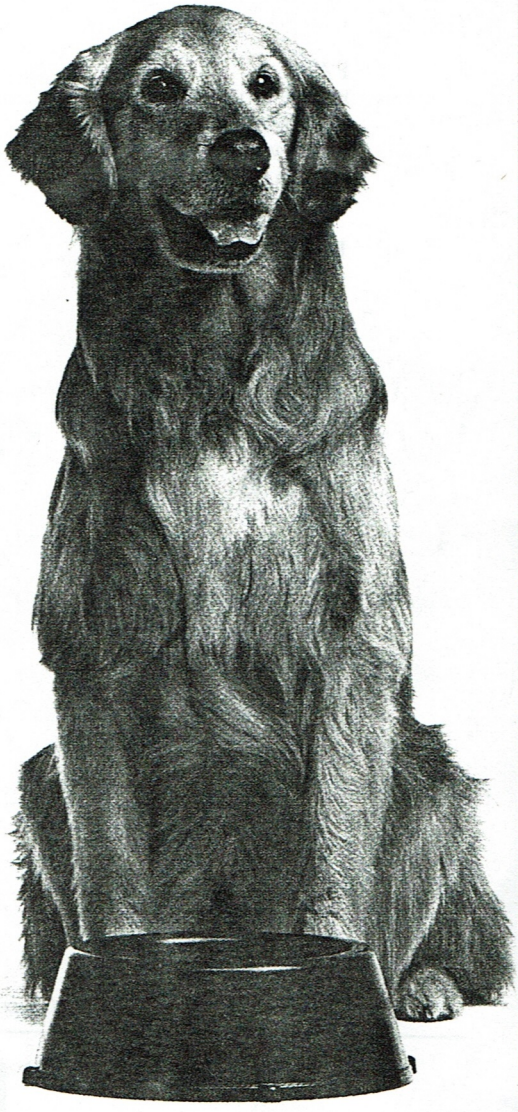
Feed *That* Dog!

A COMPLETE GUIDE TO DOG NUTRITION

8-PART NUTRITION SERIES

- ✔ **Find** out how dog food ingredients affect your dog's health
- ✔ **Learn** about the proper balance of vitamins and minerals
- ✔ **Master** the reading of dog food labels to buy your dog the right food
- ✔ **Understand** the relationships between biological stages and dietary needs



By John Cargill, MA, MBA, MS and Susan Thorpe-Vargas, MS

Acclaimed series reproduced by DOGWORLD
The World's Largest All Breed Dog Magazine

8-PART NUTRITION SERIES

Feed *That* Dog!

A COMPLETE GUIDE TO DOG NUTRITION

PART I
Knowing how dog food ingredients affect your dog's health will keep you in step with its changing dietary needs
PAGE *2*

PART II
The proper balance of vitamins and minerals is essential to a healthy diet for your dog
PAGE *6*

PART III
Dog food labeling can be confusing and sometimes requires reading between the lines
PAGE *11*

PART IV
The authors explain the chemical structures of natural and synthetic antioxidants and their use in preserving dog foods
PAGE *18*

PART V
Some synthetic antioxidants may lead to diet deficiencies that contribute to reproductive difficulties and immune system failure
PAGE *22*

PART VI
Evidence suggests that common substances may interact with some antioxidants in ways that increase their carcinogenic effects
PAGE *24*

PART VII
Feeding homemade food or supplementing store-bought kibble allows better control of what your dog eats and may help identify allergies
PAGE *28*

PART VIII
Home-cooked meals put you in charge of your dog's nutrition, but they can be costly and time-consuming to prepare
PAGE *31*

INDEX
PAGE *37*

Cover photo courtesy of Sensible Choice® Pet Foods

DOG WORLD

The World's Largest All Breed Dog Magazine

Part I

Knowing how dog food ingredients affect your dog's health will keep you in step with its changing dietary needs

This series of articles addresses canine nutritional requirements, ingredients commonly found in dog foods, how to read dog food labels and concerns over the use of various antioxidants as preservatives. This series, with its graphs and charts, is designed to be retained as a reference. While it will not replace a stack of veterinary and medical texts in nutrition, it is a relatively in-depth look at both the good and the bad in commercial canine nutrition. While there are good dog foods available, there are also very poor ones and you need to be able to tell them apart.

To set the stage, please answer the following questions.

Has it ever occurred to you that:

- some manufacturers' claims concerning their dog foods may be misleading?
- some manufacturers' claims may even be false?
- some dog foods may not be sufficient to sustain life in good health?
- formulation of some dog foods may be driven not by nutritional concerns but by economic and cost concerns? (Think profit margin.)
- it may matter less that dog foods meet well-documented nutritional requirements for complete nutrition than that they can be made cheaply enough to be marketed competitively?
- saving a dollar in the dog food manufacturing and distribution process may contribute more to return on stockholders' equity than attempting to sell for a dollar more?
- many dog foods (more than one-half by some surveys) may not meet National Research Council minimum nutritional standards?
- it would cost as much to feed a dog as an equivalent-weight human if it were fed the same quality of foods?
- that it may be virtually impossible, as some dog foods claim, for one food to be suitable for all phases of life and all activity levels?

More than a century ago, the National Academy of Sciences was established as a private non-profit organization. The National Research Council is one of the councils within the National Academy of Sciences. Throughout this article, be guided by the concept: Look for the money. One does not have to do very much research to determine that those organizations with the most altruistic names tend to be industry-front.

Remembering the days I was in uniform serving in billets requiring security clearances, I marveled at just how patriotic-sounding were the organizations on the "have you ever been a member of these communist-front organizations" list. Similarly, the more altruistic a national food committee of one sort or another sounds, the greater the likelihood that its members and its controlling board of directors are drawn directly from the food industry. Here is a good example—the Nutrition Foundation. Its founding members and sustaining members are heavy hitters in the food industry.[1]

It is worthy of note that many of the major food companies are also the purveyors of animal feeds, whether directly or through subsidiary companies. Food is food is feed. Many of the manufacturing processes are the same. The differences often are little more than the color of the dyes used, the amount of sugar and salt added, the packaging and the advertising.

Interestingly enough, the Food and Drug Administration labeling requirements are often more stringent on animal feeds than they are on human foods, even baby foods.

One example: "There is no requirement for listing the percentage of meat, or any other ingredient, on the labels of foods consumed by the baby, or for that matter, for any food consumed by human beings. Ironically, this essential information is required on the labels of foods for dogs and cats."[2]

On the other hand, a quick browse through the Association of American Feed Control Officials' "Official Publication" will show that there are plenty of ingredients in foods that are less than desirable.[3]

As a high school boy in Japan in the late '50s and early '60s, I remember the national disgrace felt over the abandonment of the Karafuto dogs in Antarctica by a Japanese research team. Such a cry ensued that monies were raised to send a recovery team for the bodies of the dogs. For those who do not know it, the Japanese are not second to the British in their fanatic love of animals. Love of animals begins in Japan.

The returning Antarctic team found two Karafuto dogs still alive after a winter in the Antarctic. Their survival over an Antarctic winter was not understood until it was discovered that they had been accosting walruses, sea lions and the like, and though unable to kill them for food, they put these creatures to flight toward their holes. In their fright and haste to escape the furor of the Karafutos and to get back to water, the walruses and sea lions would defecate. The two Karafuto dogs subsisted on this waste.

Such waste is only partially processed and has a significant amount of food value. AAFCO recognizes no less than seven different forms of recycled animal waste products as feed ingredients. Don't take my word for it—look it up. If you are in the feed-manufacturing business you may buy

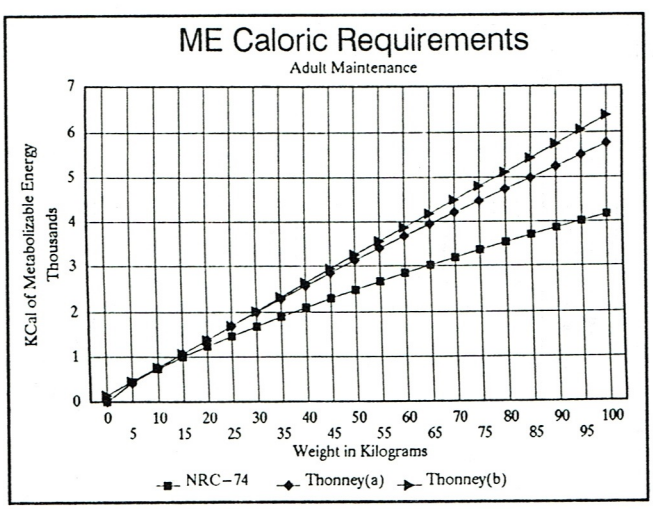


Figure 1

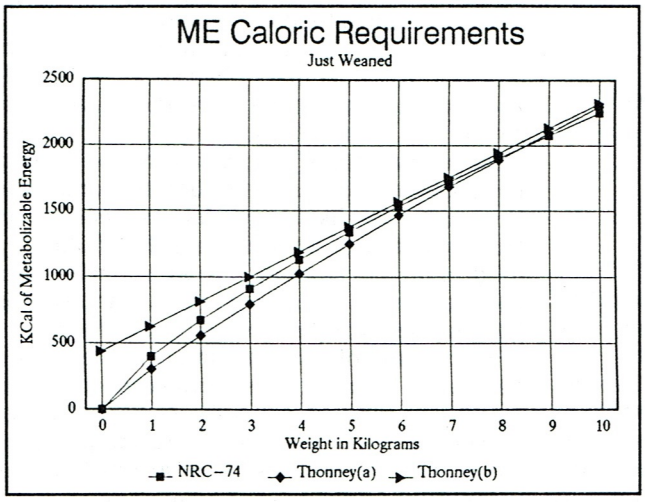


Figure 2

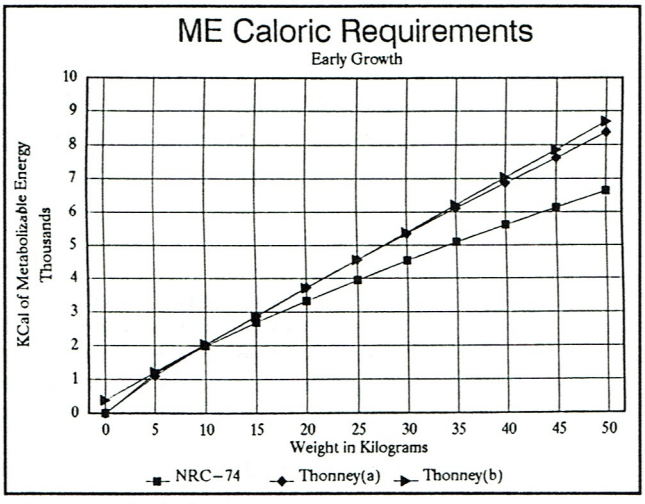


Figure 3

railroad cars of fecal matter to process into animal feeds. Copies of the "Official Publication" are available from the Treasurer, AAFCO, Georgia Department of Agriculture, Plant Food, Feed and Grain Division, Capitol Square, Atlanta, Ga. 30334; (404) 656-3637. The book is well worth the $20 the association charges.

While the preceding was a somewhat gross example of food ingredients, let me assure you that there are many more deleterious substances introduced into both animal and human diets. Often they result from not knowing how to otherwise make money from scraps and byproducts. The economic answer is simple—feed it to someone/something.

Despite the incestuous relationships among the FDA, the United States Department of Agriculture, the food manufacturers and the pharmaceutical and chemical companies, and the National Research Council, a good start still is the National Research Council, which over the years has established various feeding requirements by caloric quantity, vitamins, fats, etc. Once you understand the basic nutritional requirements, you will be better able to determine for yourself the veracity of label claims on dog food packages.

Definitions:

(1) Gross energy (E or GE) is the total combustible energy released as heat.

(2) Apparent digestible energy (DE) is the difference between GE and the gross energy in the feces excreted.

(3) Metabolizable energy (ME) is the difference between DE and energy excreted in urine. Thus ME expresses the energy content of food available to the dog and serves as a common basis for comparing the feeding value of various feed ingredients. This information is available through calling the information line at most feed manufacturers.

Metabolizable energy requirements: Cowgill (1928) did some of the first important work on canine adult maintenance requirements. He was followed by a succession of researchers (Arnold, Elvehjem, Brody and Abrams) who concurred with the Cowgill findings. In 1965, Payne broke from tradition and published ME requirements for growing, adult, pregnant and lactating dogs. In 1976 Abrams recalculated available data and reported greater ME requirements for dogs weighing less than 20 kg than those published by the NRC in 1974. Note that his calculated requirements did not vary significantly from the 1974 NRC report for larger dogs. On the other hand, Blaza (1981) found ME maintenance requirements for medium and giant breeds were higher than NRC recommendations. Specifically, he found that:

- Labrador Retrievers needed the NRC amount for their weight.
- Great Danes required 1.5 times the NRC amount.
- Newfoundlands required 1.3 times the NRC amount.

Equations: Three equations have been used exten-

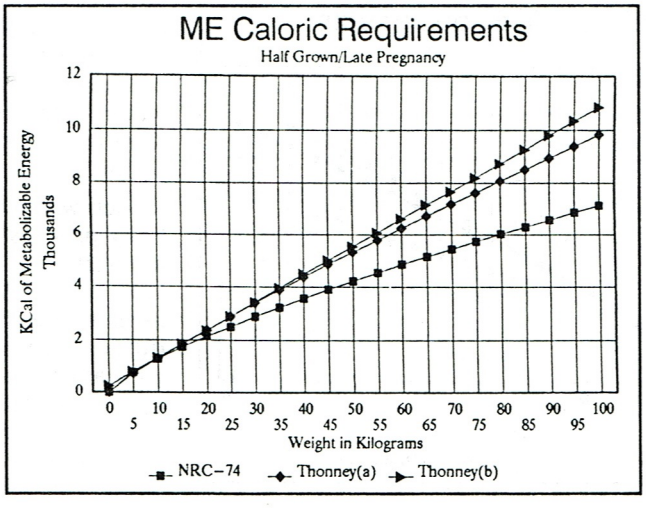


Figure 4

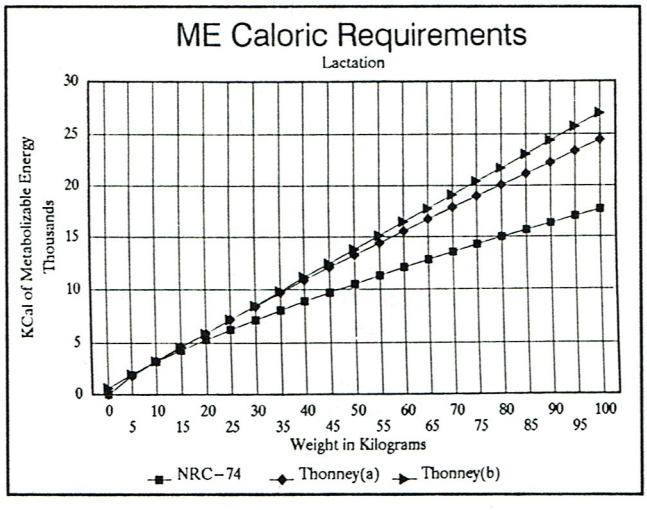


Figure 5

sively by the National Research Council of the National Academy of Sciences to model caloric requirements of metabolizable energy. Weight is in kilograms and the R-squared is the percentage of the variance in the data explained by the equation.

NRC-74 equation: $ME = 132W^{0.75}$ with $R^2 = 0.773$

Thonney(a) allometric: $ME = 99.56W^{0.879}$ with $R^2 = 0.856$

Thonney(b) linear: $ME = 144 + 62.2W$ with $R^2 = 0.856$

See Figure 1 for adult maintenance requirements described by each of the equations.

Understand that there is significant variation in the amounts of ME calories based on breed, size, environmental temperature, activity level and physiological state. Arnold and Elvehjem (1939) reported that growing puppies need 2 times as much energy per unit of body weight as do adult dogs of the same breed. Payne (1985) suggests that early growth requirements are 2.2 to 2.6 times adult maintenance. These variances from the NRC guidelines may be valid, but nonetheless not within the scope of this article.

The NRC qualifies the Thonney equations and its 1974 equation by saying, "Therefore, until more data are available, it may be advisable to determine feeding levels based on the 1974 equation predictions. These values or any others cannot be taken as absolute ME requirements for any individual or breed of dogs, since needs vary with age, activity, body condition, insulative characteristics of the hair coat, temperature, acclimatization, external environmental circumstances, and psychological temperament."[4]

With the above caveat in mind, Figures 2 through 5 show the ME caloric requirements for recently weaned, early growth, half grown/late pregnancy and lactation. I created these figures by applying the factors derived from Payne for each stage of life to the NRC-74 and Thonney equations. These factors are charted in Figure 6 and are derived directly from the NRC's "Nutrient Requirements of Dogs (Rev. 1985)." I have taken the liberty to extrapolate the graphs beyond the point of 35 kg and into the areas where feeding records are not available in the heavier weight categories. Shown also are the relative protein requirements (courtesy of Dr. Barnett, who developed Profile Performance and Pro Balance supplements and who is a nutrition consultant to Iditarod contestants).

So far we have discussed caloric requirements only. Vitally important is a proper mix of protein, fat and carbohydrates. Their relative ME caloric values are given in Figure 7. Carbohydrates and proteins both provide similar amounts of metabolizable energy per gram ingested. Fat is the real star when it comes to energy. Let's put it this way: A hard-working dog needs plenty of fats. The buying public has been conditioned to think that fat is bad and protein is good, yet there is 2.4 times as much metabolizable energy in fat as there is in either carbohydrates or protein. All are necessary, but the major source of energy is fat.

Fat: Fat is a concentrated source of energy compared to carbohydrates and protein. More importantly, it provides the essential fatty acids that are needed for metabolic regulation. Additionally, fat is a carrier of fat-soluble vitamins. The question is, "What percentage of the diet should be fat?" Campbell and Phillips (1953) have shown that puppies grow satisfactorily on a wide range of dietary fat concentrations *given that amino acid requirements are met.* The works of Seidler and Schweighert (1954) and Ontko and Phillips (1958) suggest that as long as an adequate nutrient-to-energy ratio is maintained, rather widely varying dietary concentrations of fat will support normal reproductive performance. Downey et al. (1980) found that a high-fat diet lengthened the time to exhaustion of Beagles on a treadmill by 30 percent over Beagles fed a high-carbohydrate diet. The NRC recommends that dog food contain *at least* 5 percent fat on a dry basis, of which 1 percent should be linoleic acid.[5]

Just a quick sampling of 10 commercial dog foods available at a local supermarket revealed fat percentages ranging from 8 to 12 percent, with an average around 10 percent. Contrast this with the NRC minimum of 6 percent to maintain good health. The "lean" foods generally run around 6 percent fat. Remember that the buying public is predisposed to buying feed for their dogs based upon the marketing approaches they

Figure 6

ME Energy and Protein Requirements

Physiological State	(NRC-74) Energy	(Barnett) Protein
Weaning		
Start (3 weeks)	3.0	
Finish (6 weeks)	2.8	3.00
Growth		
Early Growth	2.7	
Half Grown	1.7	2.50
Adult States		
Adult Maintenance	1.0	1.00
Pregnancy (late)	1.7	3.75
Lactation	4.2	8.00
Geriatric		2.00

Figure 7

ME Caloric Values of Feed Ingredients

Carbohydrates	3.50 kcal/gm
Proteins	3.50 kcal/gm
Fats	8.46 kcal/gm

Figure 8

Biologic Values of Feed Ingredients

Whole egg	100	Beef	78
Egg albumin	100	Soy meal	67
Casein	100	Meat scrap	50
Fish meal	92	Whole wheat	48
Liver meal	79	Whole corn	45

encounter for human products: Cholesterol is bad; fat is bad, lean is good; light is better. Of course, one has to realize that life without fat is death, and that a balanced diet is far superior to any advertised diet that fails to balance the various nutritional and energy factors.

Carbohydrates: By any other name, potatoes aren't bad. Let me quote from the NRC: "All animals have a metabolic requirement for glucose to supply energy for organs, including the central nervous system, and to supply substrate for synthesis of compounds such as pentoses and glycoproteins. To bring this closer to home for breeders, in one study bitches were fed a carbohydrate-free diet with the result that only 35 percent of the pups whelped were alive at 3 days of age.[6]

Protein and amino acids: I put proteins and amino acids in the same category to make the point that dietary protein is necessary to supply specific indispensable amino acids the body cannot synthesize in adequate quantities. "The dietary requirement of a particular protein or a mixture of proteins is determined by the ability of the protein(s) to meet the dog's metabolic requirements for amino acids and nitrogen. The closer the supply of the complement of amino acids is to the requirement, the lower the percentage of protein required in the dog's diet."[7] It further appears that amino acid requirements, as a percentage of daily food intake, are greatest at birth, lowest at maturity and increase again in old age. (See Figure 6.)

Indispensable amino acids. Through the years, the literature has achieved a consensus on 10 indispensable amino acids. There may remain some controversy over the indispensability of arginine in that Rose and Rice (1939) found that it was not necessary to maintain nitrogen equilibrium. Burns et al. (1981) determined that arginine is required in the adult dog. Following is a thumbnail sketch of the indispensable amino acids. Any feed lacking in these indispensable amino acids is lacking indeed.

• Arginine stimulates the release of metabolic hormones such as insulin, growth hormone and prolactin. Barbul et al. (1981) report that arginine also stimulates the immune response. The NRC recommends 274 mg/kg/day for growth (1.37 g/1,000 kcal [kilocalories] ME) and 21 mg/kg/day for mature dogs.

[Author's note: After reading the above on arginine, it should be obvious that a puppy would have to eat 13 times as much adult food as puppy food to ingest a sufficient amount of arginine for growth (274/21 = 13). This understanding does little to support manufacturers' claims that their food is sufficient for all stages of a dog's life. This note applies also to several other essential amino acids.]

• Histodine is required to maintain plasma and muscle histodine concentrations, muscle carnosine, hematocrit and serum albumin. The NRC recommends 98 mg/kg/day (0.49 g/1,000 kcal ME).

• Leucine, isoleucine and valine are required to optimize growth and nitrogen balance. The NRC recommendation for growth is 159 mg/1,000 kcal ME of leucine, 98 mg/1,000 kcal ME of isoleucine and 105 mg/1,000 kcal ME of valine. For the mature dog, Ward (1975) recommends 84, 48, and 60 mg/kg/day for leucine, isoleucine and valine, respectively.

• Lysine is required for maximum growth and nitrogen balance. Diets containing excess lysine result in significantly lower growth rates compared to diets containing the optimal lysine concentration of 0.58 percent. The NRC recommendation is 1.4 g/1,000 kcal ME. Ward (1975) recommends 50 mg/kg/day for the adult dog.

• Methionine is required for optimum growth and nitrogen balance. Work by Blaza et al. (1982) suggests that the dog's breed may influence methionine requirements, as a significant difference was found between Labradors and Beagles. Also, Blaza's work indicates that methionine is available from isolated soy preparations, and this must be considered in evaluating the adequacy of diets containing soy meal, etc. The NRC recommends 1.06 g/1,000 kcal ME.

• Phenylalanine and tryosine are aromatic amino acids essential for maintaining the nitrogen balance. It appears that an undetermined amount of the phenylalanine requirement can be met by tryosine. Basing its recommendation on data from other species of mammals, the NRC recommendation is 1.95 g/1,000 kcal ME total aromatic amino acids, of which 50 percent can be supplied as tyrosine (phenylalanine 51 mg/kg/ day; tyrosine 85.8 mg/kg/day).

• Threonine is required for optimal growth, feed efficiency and nitrogen retention for nitrogen balance. Threonine may also be required to maintain neurological function, as neurological dysfunction has been reported by Titchenal et al. (1980) in kittens fed a threonine-deficient diet. Similar findings have not yet been reported in dogs. The NRC recommendation is 44 mg/kg/day in the mature dog and 254 mg/kg/day (1.27 g/1,000 kcal ME) for growth.

• Tryptophan is required to maintain nitrogen balance. The NRC recommendation is 13 mg/kg/day in the mature dog and 145 mg/day/kg$^{0.75}$ (equivalent to 0.17 percent dietary tryptophan).

Here are some suggested general requirements for feeding at different life stages.

• For growth: The balance of diets is critical. Protein requirements are controversial. "Considerable debate remains regarding the interpretation of a value for protein requirement for nitrogen equilibrium and the potential benefits of higher intakes to maintain tissue protein stores."[8] Campbell and Phillips (1953) reported that adding fat to a 19.7 percent protein diet inhibited growth of puppies. They found normal growth rate could be restored by supplementing with 0.3 percent methionine.

Ontko et al. (1957) reported that for growing Beagles and German Shepherds a 20 percent fat diet required 25 percent protein; a 30 percent fat diet required 28.9 percent protein.

Burns et al. (1982) reported Beagle puppies at 8 to 10 weeks of age need 15 percent protein with diet ME of 4.2 kcal/g; pups 13 to 17 weeks of age need 11.7 percent protein with diet ME of 4.2 kcal/g.

NRC recommended 9.5 percent protein with diet ME of 3.3 kcal/g to satisfy essential and indispensable amino acid requirements of the growing dog.

• For adult maintenance: Kade et al. (1948) found 6.5 percent adequate to satisfy nitrogen equilibrium requirements in the mature dog. Wannemacher and McCoy (1966) found 6 percent protein in a diet ME of 3.5 to 4 kcal/g met the protein needs of the older dog.

• For reproduction and lactation: "The protein and amino acid needs for reproduction and lactation have not been well defined."[9] Ontko and Phillips (1958) fed a control group of mature Beagle and Cocker Spaniel bitches a 20 percent protein diet for 2.5 years. The treatment group was supplemented with 10 percent fresh liver, 5 percent casein, 2 percent liver extract or 5 percent egg white with a result of increased vigor of new-

born pups and 22 to 35 percent reduction in postnatal mortality over the control group, which had a 62 percent mortality rate. By way of contrast, Visek et al. (1976) fed Beagle bitches 25 to 26 percent protein diets with the result of 85 percent live births. The lesson here is so obvious that my original idea for the title of this series was "Feed that bitch!"

• For muscular activity: Kronfeld et al. (1977) indicate that consumption of a high-protein (52.8 percent), high-fat (36.7 percent) diet may improve performance of sled dogs over feeding a diet high in carbohydrates. The dogs acclimated to the high-fat, high-protein diet without ill consequences and had higher oxygen capacity. Iditarod sled dogs traditionally eat 40 percent of a good grade commercial food supplemented by some 60 percent of proteins, vitamins, minerals and high-quality meats. In essence, the commercial food has become the supplement!

For extreme muscular activity, the concept of biologic value of food comes into play. Dogs must be able to ingest sufficient quantities of feed to support their activity level, much as ultra-marathoners and cyclists must eat their way through races. Figure 8 shows the biologic values of commonly used feed ingredients. It is not by accident that the ingredients most commonly used in commercial feeds are soy, wheat and corn, which must be ingested in relatively large amounts and which result in relatively large amounts of stool. Sixty percent is a reasonable biologic value for a good dry dog food. Eighty percent is a reasonable digestibility value for a good dry dog food. This leaves us with a net utilization factor of 48 percent (0.6 x 0.8). The rest is stool and urine. This explains why coyote scat are so small for the size of the animal in comparison with domestic dogs fed commercial feed. The coyotes are subsisting on diets with significantly higher biologic values. For those of you involved with racing, field trials, sledding or cold-weather "dogging," I would recommend you obtain copies of references 10 and 11.

References:

1. Nutrition Foundation *founder members* included American Can, American Sugar Refining, Beechnut, California Packing, Campbell Soup, Coca-Cola, Container Corp., Continental Can, Corn Products Refining, General Foods, General Mills, H.J. Heinz, Libby McNeil & Libby, National Biscuit, National Dairy Products, Owens Illinois Glass, Pillsbury Flour Mills, Quaker Oats, Safeway, Standard Brands, Swift and United Fruit. *Sustaining members* included Abbott's Dairies, American Home Foods, American Lecithin, Bowman Dairy, Continental Foods, Crosse & Blackwell, Curtis Candy, William Davies, R.B. Davis, Drackett, Flako, Gerber, Golden State, Lab, Knox gelatin, McCormick, Minnesota Valley Canning, National Sugar Refining, Nut & Chocolate, E. Prichard, Red Star Yeast, Stouffer, Weston and Zinsmaster.

2. Hunter, B.T., "Consumer Beware," New York, Simon and Schuster, 1991, p. 306.

3. Association of American Feed Control Officials. "Official Publication," 1991. ISBM 1-878341-01-04.

4. Subcommittee on Dog Nutrition, Committee on Animal Nutrition, Board on Agriculture, National Research Council, "Nutrient Requirements of Dogs (Rev. 1985)," Washington, D.C., National Academy Press, 1985, p. 3.

5. Ibid., p. 7.

6. Ibid., p. 7.

7. Ibid., p. 9.

8. Ibid., p. 14.

9. Ibid., p. 14.

10. Costill, D.L., "Fats and Carbohydrates as Determinants of Athletic Performance, Nutrition and Athletic Performance," Haskell, Zurich, 1981, pp. 16-28.

11. McNamara, J.H., "Nutrition for Military Working Dogs Under Stress," Veterinary Medicine Strategic Air Command, Vol. 67, pp. 615-623.

Part II

The proper balance of vitamins and minerals is essential to a healthy diet for your dog

Conclusions from "Feed that dog! Part I" (July 1993 issue): Caloric nutritional requirements vary significantly from one dog to another and among breeds given differing environmental and work conditions. The National Research Council-74 equation is generally accepted as the starting point for determining caloric nutritional requirements. Fats, carbohydrates and proteins (to include the indispensable amino acids) are all essential to a balanced diet. Any diet deficient in one of these areas is deficient overall.

Ratios between fat and protein in a diet are particularly important. Biologic values of feed ingredients vary widely. No one food can even come close to meeting the requirements of all stages of a dog's life. Pay no heed to advertisements to the contrary. The "Official Publication" of the Association of American Feed Control Officials and the National Research Council's "Nutrient Requirements of Dogs (Rev. 1985)" are particularly useful in evaluating dog food.[1,2]

Minerals: If you thought from Part I that pinning down caloric, fat and protein requirements was like nailing jelly to a tree, you will find that mineral and vitamin requirements are even less well understood. The following equivocation is taken from the NRC: "It is common practice to include all the minerals shown to be required by other mammals in the formulation of dog diets, even though the quantitative requirements for all minerals has not been established experimentally for this species. The mineral concentrations used in dog diets are generally based on estimates extrapolated from the requirements of other species; from data obtained from studies that involve dogs and that, although not designed to establish nutrient requirements, nevertheless yielded nutritional information; or from experience with diets that have resulted in acceptable performances in dogs."[3]

While in the truest sense minerals are minerals are minerals, availability is an important variable. For example, iron is poorly utilized by the body, varying from 2 to 10 percent or so. This absorption rate can be improved through chelation, which is the process by which the mineral is changed into a digestible form. "Amino acid-bound chelated materials provide three to ten times greater assimilation than the non-chelated ones."[4] Common mineral supplements, such as bone meal and dolomite, are often not very useful unless chelated, as the natural chelation process is relatively inefficient. Thus, the majority of minerals, while necessary to good

Canine Dietary Mineral Requirements

Mineral	Per kg of Body Weight/Day Growth	Per kg of Body Weight/Day Adult Maintenance	Mineral Requirements for Growth (NRC-85) Per 1,000 kcal ME	Mineral Requirements for Growth (NRC-85) Dry Basis 3.67 kcal ME/g	Human Adult RDA Comparison[24]
Calcium [1]	320 mg	119 mg	1.6 g	0.59 %	1,013 mg
Phosphorus[1]	240 mg	89 mg	1.2 g	0.44 %	962 mg
Potassium	240 mg	89 mg	1.2 g	0.44 %	[6]
Sodium [2]	30 mg	11 mg	0.15 g	0.06 %	?
Chloride [2]	46 mg	17 mg	0.23 g	0.09 %	[6]
Magnesium	22 mg	8.2 mg	0.11 g	0.04 %	400 mg
Iron	1.74 mg	0.65 mg	8.7 mg	31.9 mg/kg	18 mg
Copper [3]	0.16 mg	0.06 mg	0.8 mg	2.9 mg/kg	2 mg
Manganese [4]	0.28 mg	0.10 mg	1.4 mg	5.1 mg/kg	n/a
Zinc [4]	1.94 mg	0.72 mg	9.7 mg	35.6 mg/kg	n/a
Iodine [5]	0.032 mg	0.012 mg	0.16 mg	0.59 mg/kg	150 µg
Selenium [6]	6.0 µg	2.2 µg	0.03 mg	0.11 mg/kg	[6]

Notations:
1. Calcium to phosphorus ratio 1.3
2. Sodium to chloride ratio 1.5
3. Toxic
4. Slightly toxic
5. Moderately toxic
6. Highly toxic

(3-6 by Association of American Feed Control Official definitions)

Figure 1

health, are excreted.

More specifically, there is limited published quantitative data available from which to make estimates of mineral requirements in dogs. Further complicating the problem is that the interactions among dietary mineral concentrations, the availability of minerals in different compounds, the difference in feed manufacturing techniques (temperature and pressure) and the requirements of different breeds of dogs has made it difficult to state with any certainty the mix of minerals required. The NRC has a working hypothesis (my words) of the dietary mineral requirements and these are what I will be using in this article.

Note what the NRC says: "Since publication of the last revision (NRC, 1974) of this report, data have not been published that would substantially alter the estimated mineral requirements of dogs."[5] Note that the toxic effects of feeding elevated concentrations of certain minerals have been determined and are published in the NRC's "Mineral Tolerance of Domestic Animals."[6]

As with proteins and fats, biologic availability varies considerably from one source to the next. As with proteins and fats, the differences in mineral requirements for growth, gestation, lactation and maintenance vary considerably and are not well established. "As energy intake increases in relation to the extra demands of milk production or exercise, daily intake of minerals would be expected to increase."[7] NRC estimates are based upon the highest requirements throughout the dog's life. Therefore, any feed meeting the NRC mineral requirements can be accepted as meeting the mineral requirements at any given stage of the animal's life.

Before going any further, one caveat: "The ash fraction of dog food represents the total mineral content of dog diets."[8] It appears that 4 to 5 percent ash in the dry matter of a dog food is sufficient to provide the entire requirement of minerals in a dog food; however, experience with commercial dry dog foods indicates that 7 to 9 percent is more common. "High dietary ash may, however, indicate a compromise in diet quality."[9]

Calcium and phosphorus: Consider calcium and phosphorus together because "the ratio of dietary calcium and phosphorus may be as important for good nutrition but is of lesser significance than the absolute concentration of these minerals."[10] By most accounts, once you lose the calcium to phosphorus ratio of between 1.2 to 1.4 (by weight) the requirement for vitamin D increases. There is a problem with vitamin D supplementation of diets deficient in calcium: Vitamin supplementation of diets low in calcium can cause pathological fractures,

Canine Dietary Vitamin Requirements

Vitamin	Vitamin Requirements Per kg of Body Weight/Day Growth	Vitamin Requirements Per kg of Body Weight/Day Maintenance	Vitamin Requirements For Growth (NRC-85) Per 1,000 kcal ME	Vitamin Requirements For Growth (NRC-85) Dry Basis 3.67 kcal/ME/g	Human Adult RDA Comparison[25]
Vitamin A	202 IU	75 IU	1,011 IU	3,710 IU/kg	5,000 IU
Vitamin D	22 IU	8 IU	110 IU	404 IU/kg	400 IU
Vitamin E	1.2 IU	0.5 IU	6.1 IU	22 IU/kg	30 IU
Vitamin K	-------see text-------		------- see text-------		
Thiamin (B1)	54 µg	20 µg	0.27 mg	1.0 mg/kg	1.5 mg
Riboflavin (B2)	100 µg	50 µg	0.68 mg	2.5 mg/kg	1.7 mg
Pantothenic Acid	400 µg	200 µg	2.7 mg	9.9 mg/kg	10 mg
Niacin	450 µg	225 µg	3.0 mg	11.0 mg/kg	20 mg
Pyridoxine (B6)	60 µg	22 µg	0.3 mg	1.1 mg/kg	2 mg
Folacin (Folic Acid)	8 µg	4 µg	0.054 mg	0.2 mg/kg	400 µg
Biotin (H)	-------see text-------		------- see text-------		300 µg
Vitamin B12	1 µg	0.5 µg	7.0 µg	26 µg/kg	6 µg
Choline	50 mg	25 mg	340 mg	1.25 g/kg	
Vitamin C	-------see text-------		------- see text-------		60 mg

Figure 2

lameness, abnormal stance and loss of skeletal density (Campbell, 1962).

If a little is good, it does not follow that a lot is better. I want to make this point very clearly. Hedhammer et al. (1974) conducted a study of over-nutrition and skeletal disease. They found that Great Dane puppies fed a dry basis diet of 36 percent protein, 40 percent carbohydrate, 14 percent fat and 10 percent ash resulted in chondro-osseous (cartilage bone) changes manifested in lameness and skeletal pain, enlargement of the costochondral (cartilage bone) junctions and the epiphyseal-metaphyseal (points where the bone seals off as it matures) regions of the long bones, hyperextension of the carpus and sinking of the metacarpo- and metatarsophalangeal joints (low bastions in a dog). Henrickson (1968) fed adult Beagles a diet of 0.12 percent calcium and 1.20 phosphorus (calcium to phosphorus ratio of 0.1, a far cry from the 1.2 to 1.4 recommended ratio). Progressive loss of alveolar bone (located in the jaw) was so extreme that by 12 months the incisor teeth became "easily detached." No such problems were noticed in the control group fed 0.54 percent calcium and 0.42 percent phosphorus (1.3 percent calcium to phosphorus ratio). NRC recommends 1.6 g calcium and 1.2 g phosphorus per 1,000 kcal ME (ratio of 1.33).[11]

Potassium: You can expect commercial dry dog food concentration of potassium to vary between 0.7 and 0.85 percent. Abbrecht (1972) found that dogs can be severely depleted of potassium in 30 days and subsequently be repleted in 14 days. Lack of potassium results in poor growth, restlessness, muscular paralysis, a tendency toward dehydration and lesions of the heart and kidney. Note also that prednisone, a steroid commonly prescribed for various skin and coat allergies, causes a loss of potassium and retention of sodium and that too much sodium can cause further loss of potassium. NRC recommends 1.2 g/1,000 kcal ME.

Sodium and chlorine: Like calcium and phosphorus, sodium and chlorine are considered together because of their close metabolic association. A sodium to chlorine ratio of 1.5 is now considered adequate for dogs given 0.15 g/kcal ME of sodium and 0.23 g/kcal ME chlorine. Sodium chloride deficiency in dogs is manifested by fatigue, decreased utilization of protein, decreased water intake, inability to maintain water balance, retarded growth, dryness of skin and loss of hair.

Magnesium: Published dietary requirements for this mineral are inconsistent; however, dietary concentrations of 0.11 g/1,000 kcal ME are recommended by NRC. Deficiency results in anorexia, vomiting, decreased weight gain and hyperextension of the front legs in puppies, ataxia (a clumsy, uncoordinated gait), convulsive seizures, and alterations in sodium and potassium transport and a wide range of extreme mineralized lesions.

Iron: Both iron and copper prevent anemia. Availability of iron varies considerably from one feed ingredient to the next. For example, iron from spinach is less than half as available as iron from wheat bran. Similarly, the iron of inorganic salts, liver, heart muscle and soybeans is 50 percent or more available, whereas the iron from oysters, alfalfa, spinach, blood, wheat, oats and yeast is half of that (Elvehjem et al., 1933, 1934 and Sherman et al., 1934). It seems that 1.32 mg dietary iron per kg of body weight per day meets the needs of both puppies and adult dogs; thus the NRC recommends 8.7 mg iron per 1,000 kcal of dietary ME. Iron is toxic in large concentrations: ferrous sulfate at 0.012 g/kg of body weight; ferrous carbonate at 3 g/kg of body weight.

Copper: Copper, like iron, prevents anemia and is essential for proper utilization of vitamin C. The copper requirements for the majority of dog breeds seem to be low—about 0.8 mg copper per 1,000 kcal ME. Tinedt et al. (1979) reported copper toxicosis in Bedlington Terriers fed commercial feeds containing 5 to 10 mg copper per kg of diet.

Manganese: The reader is on his or her own as to how much manganese is required. "There is essentially no published information regarding the manganese requirements for dogs, nor is there any description of the deficiency signs in this species."[12] Since manganese is known to play a role in catalyzing several metabolic reactions, it is generally included in dog feeds. The NRC recommendation is 1.4 mg/1,000 kcal ME.

Zinc: Zinc remains controversial. Fisher (1977) fed more than 800 Beagles 32 mg/kg zinc of diet without clinical signs of zinc deficiency. Sanecki et al. (1982) found 90 mg/kg of diet the minimum to avoid parakeratosis (thickening of the skin), ulcerations and inflammation of the skin. In diets where high levels of calcium and/or phytate (phosphorous salts) are present, Sanecki's 90 mg/kg of zinc in the diet seems to be more important. Some evidence exists to suggest that zinc is required for the synthesis of DNA. The NRC recommendation is 9.7 mg/1,000 kcal ME.

Iodine: As early as 1909 Marine and Lenhart showed that dogs required iodine to prevent goiter. Serum T4 and T3 (thyroid) levels are unaffected with iodine intake at 90 µg (micrograms)/day in Beagles (Belshaw et al., 1975). At 20 to 50 µg/day, T4 was significantly reduced; however, T3 was unaffected. T3 and T4 are important components of the immune system.[13,14] In areas where human goiter is prevalent, it has been reported that cretinism (stunted physical development resulting in a broad skull and short, thickened legs) in local dogs was also prevalent. Deficiency results in skeletal deformities, delayed shedding of deciduous teeth, hairlessness, dullness, apathy and timidity. Webster et al. (1966) reported that excessive amounts may be toxic. The NRC recommends 0.16 mg/1,000 kcal ME.

Selenium: Selenium has a checkered history. Years ago, it was thought that suburban dogs were not receiving enough selenium because they no longer were ingesting dirt like their country cousins. More recently, it has been found that various preservatives affect the ability of vitamin E to convert selenium to selenides, thus affecting availability. The solution has been to increase the amount of vitamin E. It is now understood that selenium and vitamin E are synergistic. Selenium deficiency is manifested in general malaise, muscular weakness, anorexia, depression, dyspnea (interruptions in breathing) and eventual coma, and necrosis (cellular breakdown) of the myocardium (lining of the heart). Antioxidant suppression of selenium utilization will be covered in detail in later articles in this series. NRC recommends 0.03 mg/1,000 kcal ME.

Fluorine: The requirement for fluorine has not been established for dogs. Biester et al. (1936) reported that sodium fluoride at amounts found in municipal drinking water caused mottling of tooth enamel during the period of calcification of permanent teeth. The NRC makes no recommendation for levels of fluorine.

Trace elements: Dietary requirements for trace elements are not understood; however, it has been shown that cobalt (a component of vitamin B12) is not required if adequate amounts of vitamin B12 are provided. Trace elements that may be required are: "molybdenum, tin,

silicon, nickel, vanadium, chromium, lead and perhaps arsenic."[15]

Vitamins: There are many unknowns in vitamin requirements; however, it is safe to say that the vitamin requirements for gestation, lactation and muscular effort are generally related to energy intake. One of the most difficult problems in formulating dog foods is that several vitamins are unstable and are destroyed by light, heat, oxidation, moisture, rancidity and by certain other mineral elements. Note that excessive intake of vitamins A and D is harmful. As with proteins, fats, carbohydrates and minerals, numerous interactions between vitamins and between vitamins and minerals take place. The relative mix of vitamins, therefore, is important.

"Vitamins regulate our metabolism through enzyme systems. A single deficiency can endanger the whole body."[16] Water-soluble vitamins (vitamins C and E) are quickly eliminated and must be replenished frequently; fat-soluble vitamins (A, D, E and K) remain in the body for 24 hours or so and may become concentrated in the liver.

Vitamin A: Vitamin A is fat-soluble and requires fats as well as minerals to be properly utilized. As a fat-soluble vitamin, it can be stored for a short period and need not be replenished every day. Some of the best natural sources include fish liver oil, liver, carrots, dark green and yellow vegetables, eggs and dairy products. "Polyunsaturated fatty acids with carotene work against vitamin A unless anti-oxidants are present."[17]

Vitamin A deficiency was one of the first deficiencies studied experimentally in the dog. Frohring (1935, 1937) fed a vitamin A-deficient diet to Beagle puppies. He determined that 100 International Units (IU) vitamin A per kg of body weight was lost from the liver. Several researchers have studied the vitamin A activity of various carotene sources, such as in cod liver oil and in carrots, where both sources seem to be equally well utilized. Excessive intake of vitamin A has resulted in weight loss, extreme tenderness of the extremities, decreased bone lengths and thickness due to premature closure of growing bone plates in the long bones, degenerative lesions in arteries and veins of the myocardium and the gall and urinary bladders. The NRC recommendation is 1,011 IU per 1,000 kcal ME, or 3,710 IU/kg of feed.

Vitamin D: The dog has been widely used as a model for vitamin A and D effects in association with calcium and phosphorus on bone growth and development. Calcium, phosphorus and vitamin D are all interrelated. It is now recognized that vitamin D is a hormone that can be synthesized when the skin is exposed to ultraviolet sunlight. How much vitamin D is needed is a function of concentrations of calcium and phosphorus, and the calcium to phosphorus ratio. It varies considerably with biological stages of life. Vitamin D deficiency is frequently observed simultaneously with deficiency or imbalance of calcium and phosphorus.

Vitamin E: Vitamin E (tocopherol) has come into popularity of recent years. It is fat-soluble and is stored in the liver, fatty tissues, heart, muscles, testes, uterus, blood and various glands. While there are eight tocopherols (alpha-, beta-, gamma-, delta-, epsilon-, zeta- and eta-), only the most effective tocopherol, alpha, is generally found as an additive to dog foods. Good natural sources are wheat germ, soybeans, vegetable oils, leafy greens and whole grains. Heat, oxygen, freezing, food processing, iron and chlorine all reduce the availability of vitamin E.

Anderson et al. (1939) showed the dietary need for vitamin E early on, but recently more attention has been paid to the relationships between vitamin E and selenium. Both nutrients are necessary and important in combating the destructive effect of free radicals and preventing peroxidation (self-oxidation) of cell membranes. Free radicals are unbalanced ions actively seeking to balance themselves. They can be dangerous because they can collect electrons from other compounds, thereby setting off a chain reaction. Tappel (1980) goes as far as to show that vitamin E quenches free radicals in polyunsaturated fatty acids (PUFA) of membrane phospholipids. Hayes et al. (1969) showed that even as much as 100 mg alpha-tocopherols is inadequate to prevent lipofuscin (fatty pigment) formation when a large amount of PUFA is fed after the tocopherols have been removed.

Vitamin E ratios are important. Harris and Embree (1963) suggested a dietary alpha-tocopherol to PUFA ratio (mg/g) of 0.6 as a minimum against PUFA peroxidation. Just as an aside, Bieri and Evarts (1973) report that human diets in the United States are estimated to have an average alpha-tocopherol to PUFA ratio of 0.41 to 1 without signs of vitamin E deficiency. On the other hand, there are a lot of people out there with stiff joints. . . . Elvehjem et al. (1944) found that 0.62 mg (0.68 IU)/kg of body weight per day would not sustain normal reproduction in Fox Terriers fed unsweetened, irradiated evaporated milk.[18] Additionally, vitamin E is necessary for proper immune system function. Combined vitamin E-selenium deficiency gives rise to a whole host of problems which will be covered in greater detail in following articles in this series. In the meantime, stay away from rancid fats and oils because of their ability to destroy tocopherols. If PUFA amounts are increased, a corresponding increase in vitamin E is warranted.

Vitamin K: The metabolic need for the fat-soluble vitamin K (menadione) has been well established in dogs. It is essential to the synthesis of prothrombin (one of a class of clotting factors) by the liver, without which there would be massive hemorrhaging. Good natural sources are leafy green vegetables, alfalfa, egg yolk, soy and fish liver oils and kelp. "A simple vitamin K deficiency has not been described in the dog."[19] The NRC has set no requirement for vitamin K, as it seems to be provided in several ways in a normal diet. However, broad spectrum antibiotics tend to reduce the availability of vitamin K.

Thiamin (vitamin B1): Vitamin B1 is water-soluble and, like all of the B-complex vitamins, must be replaced daily. There is a special synergy with B-vitamins, thus B1, B2 and B6 are more potent together than taken separately. Thiamin requirements vary with physiological condition and diet. Several researchers have reported that inclusion of penicillin, lactose, sorbitol and ascorbic acid increases the requirement for thiamin in other species. Heat quickly destroys thiamin, as do some processing methods and sulfa drugs. Roche (1981) reports losses of 74 percent of thiamin in some canned foods due to retorting and storage for 14 days. Thiamin deficiency results in weight loss, weakness and failure to grow, various neurological syndromes and sudden unexpected death. In humans, this deficiency is commonly noted as beriberi, which remains endemic to many Third World nations. NRC recommends 20 µg/kg body weight or 270 µg/1,000 kcal ME is adequate for both maintenance and growth.

Riboflavin (vitamin B2 also sometimes known as

vitamin G): B2, like B1, is water-soluble, but unlike B1 is not destroyed by normal processing heats, oxidation or acids. Good natural sources of vitamin B2 are milk, liver, kidney, yeast, leafy green vegetables, fish and eggs. As with B1, sulfa drugs destroy vitamin B2. Deficiency results in anorexia, hypothermia, progressive weakness and sudden collapse to coma. Ocular lesions have been reported. Daily intake of 50 µg/kg body weight is considered sufficient for adult dogs and 100 µg for growth.

Pantothenic acid: Pantothenic acid, also known as vitamin B5, is required for appetite, growth and antibody response. Good natural sources for pantothenic acid are meats, whole grains, wheat germ, bran, kidney, liver, heart, green vegetables, brewer's yeast, chicken and crude molasses. Enemies of pantothenic acid are heat, food-processing techniques, canning and sulfa drugs. In terminal stages of total pantothenic deficiency, dogs are spastic in the hindquarters and are subject to sudden prostration or coma. Limited evidence exists upon which to base requirements; however, the NRC recommends 200 µg/kg body weight for adults and 400 µg/kg for growth.

Niacin: Niacin is water-soluble and also known as nicotinic acid, niacinamide, nicotinamide and vitamin B3. In the 1930s, dog models were used for the study of human pellagra, a dietary condition characterized by gastrointestinal disturbances, skin eruptions and mental disorders. It was then, and is still, endemic in Third World nations. Goldberger and Wheeler (1928) found a similarity between "black tongue" in dogs and pellagra in humans. Dogs and humans subsisting almost entirely on corn mash and lard are particularly susceptible because of the low availability of niacin and deficiency of tryptophan (an amino acid) in corn. In dogs, niacin (nicotinic acid) is an end-product of tryptophan degradation.

Good natural sources include liver, lean meat, whole wheat products, brewer's yeast, kidney, wheat germ, fish, eggs, white chicken meat and avocados. In cereal grains, niacin may be in a bound form and thus not available; however, niacin is unusual in that it is relatively stable and generally not significantly damaged through cooking and storage. Handler (1943) and Krehl (1945) suggest that dogs on corn-based diets require higher levels of niacin. Deficiency is characterized by anorexia, weight loss, inflammation and hemorrhagic necrosis of the duodenum and jejunum (middle part of the small intestine), and neuronal degeneration of the spinal cord. NRC recommends 450 µg/kg body weight for growth and 225 µg/kg body weight for adult maintenance.

Pyridoxine (vitamin B6): Pyridoxine is water-soluble like vitamins B1 and B2. B6 is a combined term for pyridoxine, pyridoxal and pyridoxamine, which are closely related and function together. High-protein diets require a corresponding increased intake of vitamin B6. Good natural sources of vitamin B6 are brewer's yeast, wheat bran, wheat germ, liver, kidney, soy, blackstrap molasses, unmilled rice, eggs and oats. Pyridoxine is required to prevent anemia, anorexia, weight loss, cardiac dilatation, congestion of tissues and demyelination (the stripping of the protective covering of nerves) of peripheral nerves. NRC recommends 60 µg/kg per day for the growing dog and 22 µg/kg for adult maintenance.

Folacin (folic acid): Folacin, a water-soluble member of the B-complex family, is sometimes also known as Bc or vitamin M. Unfortunately, while dogs were used extensively by Baugh et al. (1971, 1975) and Bernstein et al. (1972, 1975) as a model for human absorption of folic acid from the gut, the extent to which intestinal synthesis meets body needs has not been determined. Krehl and Elvehjem (1945), Alfonsky (1954) and Sheffy (1964) all report that folacin deficiency depresses the immune response—*especially to canine hepatitis and canine distemper virus.* Good natural sources are deep-green leafy vegetables, carrots, liver, egg yolk, avocados, beans, whole and dark rye flour. Heat, food processing and sulfa drugs destroy folacin. NRC recommends 4 µg/kg for adults and 8 mg/kg for growth. This is equivalent to 54 µg/1,000 kcal ME.

Biotin: Biotin, also called Coenzyme R or vitamin H, is yet another water-soluble member of the B-complex family. It is somewhat unusual in that it contains sulfur and can be synthesized by intestinal bacterial. Deficiency occurs only rarely, as biotin is common to many foodstuffs and "no adequate descriptions of biotin deficiency in the dog are available."[20] Good natural sources include beef liver, egg yolk, soy flour, brewer's yeast, milk, kidney and unpolished rice. Biotin synthesis occurs in the gut.

One caution: The deficiency can be induced by feeding raw egg whites, which contain avidin capable of forming a biologically inactive complex with biotin. Another caution: Sulfa drugs and intestinally active antibiotics can inhibit or prevent synthesis of biotin, thus necessitating a dietary increase in biotin. The NRC recommends 30 µg/1,000 kcal.

Vitamin B12: Water-soluble vitamin B12 is also know as cobalamin or cyanocobolamin. The dog has been used extensively as a model of vitamin B12 absorption, but no conclusive data on dietary requirements are available; however, in humans it is known to help prevent anemia, and deficiency results in neurological disorders. Good natural sources include liver, beef, pork, eggs, milk, cheese and kidney. "In the absence of information on the requirement of dogs for vitamin B12, it is suggested that the recommended requirement for the baby pig (NRC, 1979) of 0.5 µg per kilogram of body weight be adopted for maintenance of the adult dog and twice this level (1.0 µg per kilogram of body weight) be used for growth in puppies."[21]

Choline: Choline is a lipotropic (fat emulsifier) member of the B-complex family. Of special note is that choline is one of the few substances able to penetrate the blood-brain barrier. In humans, it is reputed to help improve memory. "Circulating choline transported into the brain has an additional very important function for a special group of nerve cells that make the biochemical acetylcholine, which is released into synapses as a neurotransmitter." It provides the essential precursor used to synthesize acetylcholine.[22]

High levels of methionine and other methyl donors in the diet eliminate the need for choline. Inadequate research has been done to clearly establish requirements given the above interactions. Signs of deficiency include impairment of liver function.

As a quick aside, and worthy of consideration for those of you who compete with your dogs in Schutzhund, tracking, field and other trials requiring scent discrimination, PhosChol, a non-prescription, highly purified form of soya lecithin produced by Advanced Nutritionals, is being used by some physicians to treat loss of smell and Alzheimer's disease in humans. Good natural sources include egg yolks, brain, heart, green leafy vegetables, yeast, liver, wheat germ and lecithin. A particular caution is warranted: Lecithin can disrupt the calcium-phosphorus ratio and calcium supplementa-

tion may be required. Furthermore, large amounts of choline over an extended period of time may deplete vitamin B6. NRC recommends 25 mg/kg body weight for adult maintenance and 50 mg/kg for growth.

Vitamin C: Dogs, unlike guinea pigs, apes and humans, require no exogenous source of the water-soluble vitamin C. Puppies fed a diet devoid of vitamin C for 147 to 154 days were without ill effects. This same diet killed guinea pigs of extreme scurvy within 25 days. Vitamin C has been touted as a cure for almost everything when administered in megadoses. Do not be led into believing fad literature. Teare et al. (1980) found that 600 mg of ascorbic acid administered three times a day increased skeletal disease induced by feeding Labrador puppies excess protein, energy and calcium. Belfied (1967) proposed vitamin C as a prophylactic against canine distemper. Leveque (1969) proposed vitamin C as a treatment for kennel cough. Sheffy (1972) contradicted those studies, stating specifically that exogenous vitamin C was of no benefit in reducing clinical signs of illness associated with canine herpes virus, kennel cough or infectious canine hepatitis. The NRC states, "It is concluded that there is no adequate evidence to justify recommendation of routine vitamin C additions to the diet of the normal dog."[23]

Special foods: While vitamins and minerals are available from numerous sources, several foodstuffs need to be singled out for "honorable mention."

Kelp: This amazing seaweed probably contains more vitamins and minerals than any other single food. Kelp, not just good in soups and nigiri sushi for humans, is also being used in a number of dog foods. Kelp is also an easy source for the trace elements difficult to obtain otherwise. Not quite jokingly, and not quite seriously, it has been said that if it is not in kelp, you don't need it, and neither do your dogs.

Yeast: A wonderfood, yeast is a superior source of protein, natural B-complex vitamins, organic iron, amino acids and a whole bunch of minerals and trace elements. Yeast, in its various forms (brewer's, torula, whey), can almost be considered a whole food. Caution: Do not feed your dog live baker's yeast, as live yeast will deplete vitamins, especially the B-complex vitamins.

I have purposely avoided writing about vitamins B13 (orotic acid), B15 (pangamic acid), B17 (laetrile), P (C-complex), PABA, T, U and Inositol because no recommended daily allowances have been established for dogs or humans. Fortunately, feeding for the vitamins discussed in detail above tends to take care of providing these more controversial vitamins which are present in many common foodstuffs.

I would like to leave you with one very special caution: The subject of minerals and vitamins is exceedingly complex—if you don't know what you are doing, leave it alone. Do not supplement without having a valid scientific basis for it. You can harm your dog. Most commercial feeds are reasonably balanced with respect to vitamins and minerals.

References:

1. Association of American Feed Control Officials, "Official Publication,"1991; ISBM 1-878341-01-04.

2. Subcommittee on Dog Nutrition, Committee on Animal Nutrition, Board on Agriculture, National Research Council, "Nutrient Requirements of Dogs (Rev. 1985)." Washington, D.C., National Academy Press, 1985.

3. Ibid., p. 14.

4. Mindell, E., "Vitamin Bible," New York, Warner Books, 1991, p. 18.

5. "Nutrient," p. 15.

6. Subcommittee on Dog Nutrition, Committee on Animal Nutrition, Board on Agriculture, National Research Council, "Mineral Tolerance of Domestic Animals," Washington, D.C., National Academy Press, 1980.

7. "Nutrient," p. 15.

8. Ibid., p. 15.

9. Ibid., p. 15.

10. Ibid., p. 15.

11. Ibid., p. 16.

12. Ibid., p. 20.

13. Cargill, J.C., "Truth in advertising: breeder self-regulation," DOG WORLD Magazine, Vol. 75, No. 8, August 1990, p. 38.

14. Cargill, J.C., "Genetic Screening," *Pure-Bred Dogs/American Kennel Gazette*, January 1991.

15. "Nutrient," p. 22.

16. "Vitamin Bible," p. 4.

17. Ibid., p. 28.

18. "Nutrient," p. 26.

19. "Nutrient," p. 27.

20. "Nutrient," p. 36.

21. "Nutrient," p. 36.

22. Barnhart, E., publisher, "Physicians' Desk Reference," 43 Ed., 1989, p. 592.

23. "Nutrient," p. 38.

Part III

Dog food labeling can be confusing and sometimes requires reading between the lines

Conclusions from "Feed that dog! Part II" (August 1993 issue): Mineral dietary requirements have not been completely established through experimentation; many standards have been established by extrapolating from the requirements of other mammals. Interactions between minerals, and the availability of minerals in different compounds, and differences between manufacturing techniques contribute to make exact requirements and ratios between minerals uncertain. The same goes for vitamins.

Here are some important mineral relationships—calcium:phosphorus; sodium:chlorine

Important vitamin to mineral relationships include vitamin A:vitamin D::calcium:phosphorus; vitamin E:selenium.

Some other relationships are energy intake:mineral requirements; vitamin E:PUFA.

Many dog food labels are seldom rational or completely informative. Labeling requirements are determined politically, much as are taxes, import tariffs and the like. As with human food, labeling practices and both federal and state regulations have changed considerably over the years depending upon who exerted the greater influence in the political arena. Additionally, it is not infre-

quent that what is legal to sell in one state is illegal in another. Dog foods, like their human food counterparts, have been subject to one fad after another. For example: After the controversy concerning ethoxyquin, several dog food manufacturers which use ethoxyquin as a preservative began to tout that some of their brands were ethoxyquin-free. Others boast that they use only lamb and rice, while others still claim that only beef products will do. Then there are those who preach chicken. Some believe in the nutritional qualities of avocados, etc. There are even dog foods whose labels list "powdered cellulose." Think about that ingredient for just a minute. Sawdust meets the definition of powdered cellulose. It worked in bread during the siege of Leningrad, but it certainly was not optimal.

I used to tease my neighbor, who would bulldoze under a couple of tons of unsellable kiwi fruit each year, that he should sell it to a dog food manufacturer—it ought to have "yuppie appeal." Fortunately, he did not, and we were spared another fad dog food diet. Suffice it to say that there are enough surplus ingredients in manufacturing byproducts out there to develop fad feeds. It is not just the human food industry that creates and promotes fads and strange diets to increase sales; some dog food companies do the same.

When examining labels, given that the manufacturer did an appropriate job of determining the relative mix of minerals and vitamins (i.e., was at least close to the NRC guidelines), the major points of difference are in the potency of the feed (kcal/pound), the percentages of protein, fat, carbohydrates and ash, the first three or four major ingredients, and the types of preservatives used. Some dog fanciers have great concern over the form of the food; to my way of thinking, it matters little nutritionally whether a food is in hard-baked flakes, big chunks, little chunks or as a sloppy canned mush. There are, of course, oral hygiene advantages to hard-baked foods. There are forms of dog food which store better than others. Modern canning technology provides an extended shelf life given high-temperature canning and airtight containers. Hard-baked flakes such as Solid Gold probably store better than regular extruded dry dog food. Moist and semi-moist foods which are vacuum-packed probably do quite well also.

Two bodies of writing seem to drive what must be put on labels. First is the United States "Fair Packaging and Labeling Act"; second is the "Official Pet Food Regulations" prepared by AAFCO and the Pet Food Institute. The various states also prepare their own sets of regulations; however, in the case of feeds, most states seem to legislate regulations which, for the most part, support the AAFCO and Pet Food Institute positions.

The first thing that must appear on the principal display panels of the pet food label is "Dog Food."[1] This at least lets you know what you are working with. Next must be a statement of "Guaranteed Analysis" which must be listed in the following order: Crude Protein (Minimum Amount); Crude Fat (Minimum Amount); Crude Fiber (Maximum Amount); Moisture (Maximum Amount).

The sliding scale method of expressing a guaranteed analysis is prohibited. Instead, a minimum point value must be stated. Thus "Crude Protein 18%" is permissible, whereas "Crude Protein 15% to 18%" is not. Most dog food labels also contain the Ash Content (Maximum Amount) in addition to the above.

Now get this: "The label of a pet food shall not contain an unqualified representation or claim, directly or indirectly, that the pet food therein contained or a recommended feeding thereof, is or meets the requisites of a complete, perfect, scientific or balanced ration for dogs or cats unless such product or feeding:

"(1) Contains ingredients in quantities sufficient to provide the estimated nutrient requirements for all stages of the life of a dog or cat, as the case may be, which have been established by a recognized authority on animal nutrition, such as the Committee on Animal Nutrition of the National Research Council of the National Academy of Sciences; or

"(2) Contains a combination of ingredients which when fed to a normal animal as the only source of nourishment will provide satisfactorily for fertility of females, gestation and lactation, normal growth from weaning to maturity without supplemental feeding, and will maintain the normal weight of an adult animal whether working or at rest and has had its capabilities in this regard demonstrated by adequate testing."

You may remember from "Feed that dog! Part II" that various minerals and vitamins are required in amounts differing by more than an order of magnitude between biological stages.[2] Furthermore, labels for products suitable for only one purpose (e.g., puppy food) may so state only if:

"(a.) The pet food contains ingredients in quantities sufficient to satisfy the estimated nutrient requirements established by a recognized authority on animal nutrition, such as the Committee on Animal Nutrition of the National Research Council of the National Academy of Sciences for such limited or qualified purpose; or

"(b.) The pet food product contains a combination of ingredients which when fed for such limited purpose will satisfy the nutrient requirements for such limited purpose and has had its capabilities in this regard demonstrated by adequate testing."

Keeping the above in mind, review Table 1, which catalogs some of the general properties of commonly available dog foods. The table is not complete, as a number of manufacturers were reluctant to release Metabolizable Energy values because they tend to vary given which assay method is used to determine the caloric value. There may be some inaccuracies in the ME values, as a number of them were taken telephonically from product representatives. The question that must be asked is whether the claims made hold up under scrutiny given the widely differing nutrient requirements of the various biological stages. Table 2, presented as a less-than-subtle reminder from "Feed that dog! Part I," gives the relative requirements for various biological stages of life.

AAFCO stipulates that "if the names of more than one such ingredient are shown, they shall appear in the order of their respective predominance by weight in the product."[3] This is a major contribution to truth in labeling. Unfortunately, the pet food industry, and the state and federal legislative bodies it supports, have not seen the way clear to listing ingredients in terms of percentages of dry weight, as is done with protein, fat, fiber and moisture. Nonetheless, this gives some idea of what the contents of the food might be. The list of definitions at the end of the article defines the ingredients I found listed on dog food labels found in local grocery stores, pet stores and at several dog shows. Note the differences in label ingredients that sound almost like the same thing. You should take away from this article that labeling is very specific, and labeling terms have generally been chosen to be palatable to the buyers of dog food.

TABLE 1. Comparison of Commonly Available Dog Foods

Manufacturer	Product	ME kcal/lb	Percent Protein	Percent Fat	Top three major ingredients 1	2	3	Preservatives 1	2	3
Alpo	Beef Flavor	NA	21.0%	8.0%	yellow corn	soybean meal	meal/bone meal	BHA	Tocopherols	
	Protein Plus	NA	28.0%	11.0%	meat/bone meal	brewers rice	yellow corn	BHA	Citric Acid	
Bench & Field	Fitness	1660	26.0%	10.0%	corn	meat meal	chicken by-product	BHA	Citric Acid Citric Acid	Ethoxyquin
	20%	1510	20.0%	5.0%	corn	meat meal	cereal fines	BHA	Citric Acid	Ethoxyquin
	23% Maintenance	1550	23.0%	7.0%	corn	meat meal	cereal fines	BHA	Citric Acid	Ethoxyquin
	26% Active Adult	1590	26.0%	9.0%	meat meal	corn	cereal fines	BHA	Citric Acid	Ethoxyquin
	Extra	1800	28.0%	18.0%	meat meal	corn	animal fat	BHA	Citric Acid	Ethoxyquin
Bow Wow Brands	Bite Size	NA	21.0%	8.0%	yellow corn	wheat middings	meat/bone meal	ETQ		
Breeder's Choice	Avoderm	NA								
Eagle Products	Kennel Pack	NA	25.0%	15.0%	meat meal	yellow corn	rice flour	BHA		
Friskies	Come & Get It	NA	21.0%	10.0%	yellow corn	beef/bone meal	rice mill by-products	BHA		
Fromm	Performance	1918.7	26.0%	18.0%	poultry by-products	poultry by-products meal	oatmeal	Tocopherols	Citric Acid	
	Competition	1797.1	22.0%	15.0%	poultry by-products	yellow corn	poultry by-products meal	Tocopherols	Citric Acid	
	Maintenance	1673.8	20.0%	11.0%	yellow corn	poultry by-products	wheat flour	Tocopherols	Citric Acid	
Gaines	Cycle Adult	1601	22.0%	8.0%	yellow corn	chicken by-product meal	feeding oatmeal	BHA	Tocopherols	
Gilpa	Imperial	NA	21.0%	9.0%	cereals	meat and animal derivatives	oils & fats			
Glendale Foods	Bi-Rite	NA	18.0%	6.0%	wheat middings	yellow corn	meat/bone meal	BHA		
Hills Science Diet	Canine Maintenance	1744	22.0%	13.0%	ground corn	poultry by-product meal	soybean meal	BHA	Citric Acid	Ethoxyquin
	Performance	1995	27.0%	23.0%	ground corn	poultry by-product meal	animal fat	BHA	Citric Acid	Ethoxyquin
Iams	Eukanuba Original	1977.3	30.0%	20.0%	chicken by-products meal	corn	chicken	BHA	Ethoxyquin	
	Eukanuba Adult	1860.9	25.0%	16.0%	chicken by-product meal	rice flour	corn	BHA	Ethoxyquin	
	Chunks/minichunks	1743.2	26.0%	15.0%	chicken by-product meal	corn	rice flour	BHA	Ethoxyquin	
	Lamb & Rice	1869.8	23.0%	14.0%	lamb	rice flour	corn	BHA		
Kal Kan Foods	Pedigree Expert	NA	30.0%	15.0%	chicken by-product meal	yellow corn	corn gluten	BHA		
	Adult Conditioning	NA	23.0%	10.0%	ground corn	poultry by-product meal	corn gluten	BHA		
Kruse Country Perfection	Perfection Adult	1665	18.0%	8.0%	ground wheat	yellow corn	beef and bone meal	BHA	Ethoxyquin	
	Perfection Performance	1720	22.0%	10.0%	ground wheat	yellow corn	beef and bone meal	BHA		
Natural Balance	Dick Van Patten	1725	25.0%	16.0%	chicken meal	wheat flour	lamb and beef meal	Tocopherals	Ascorbic Acid	
Natural Life	Adult	1840	26.0%	12.0%	corn	poultry meal	whole wheat	Tocopherals	Citric Acid	
	Condition	2379	28.0%	18.0%	poultry meal	brown rice	grain sorghum	Tocopherals	Citric Acid	
Nature's Recipe	Maintenance Lamb and Rice	1565	20.0%	10.0%	whole wheat	lamb meal	brown rice	Tocopherals	Ascorbic Acid	
	Maintenance Veniso Meal and Rice	1565	22.0%	10.0%	venison meal	brown rice	barley	Tocopherals	Ascorbic Acid	
	Maintenance Lamb Meal, Rice & Barley	1565	20.0%	10.0%	lamb meal	brown rice	barley	Tocopherals	Ascorbic Acid	
Nutro	Natural Choice	1790	21.0%	12.0%	lamb meal	rice	wheat flour	Tocopherals		
	Nutro Max	1964	26.0%	16.0%	chicken meal	wheat flour	rice	Ethoxyquin		
Pedigree	Mealtime		21.0%	8.0%	ground corn	meat/bone meal	ground wheat	BHA		
	Rice and Vegetable		21.0%	8.0%	ground corn	meat/bonemeal	rice	BHA		
Pet Nutrional Systems	Adult Blend	1334	26.0%	16.0%	lamb meal	ground rice	chicken meal	Tocopherols		
	Performance Blend	1450	30.0%	20.0%	lamb meal	ground rice	chicken meal	Tocopherols		
Precise	Foundation	1687.2	24.0%	14.0%	chicken meal	brown rice	whole wheat	Tocopherols	Vitamin C	Vitamin E
	Endurance	1769.5	28.0%	18.0%	chicken meal	brown rice	yellow corn	Tocopherols		
	Sensicare	1616	22.0%	12.0%	lamb meal	brown rice	oats	Tocopherols		
Quaker Oats Ken-L-Ration	Tender Chops	NA	16.0%	8.0%	wheat	soy flour	corn syrup	BHA	Tocopherols	
	Kibbles & Bits	NA	19.0%	8.0%	yellow corn	soy flour	soybean meal	BHA	Tocopherols	Citric Acid
	Choice Blend	NA	18.0%	7.0%	yellow corn	wheat flour	beef/bone meal			
Ralston Purina	Lucky Dog	NA	21.0%	8.0%	yellow corn	wheat	corn gluten meal	Ethoxyquin		
	Benji's Moist & Chewy	NA	18.0%	7.0%	water	wheat	corn	BHA	Ethoxyquin	
	Hi Pro	1663	27.0%	10.0%	yellow corn	corn gluten meal	meat/bone meal	BHA		
	One Dog Formula	NA	26.0%	16.0%	chicken	yellow corn	ground wheat	Ethoxyquin		
	Dog Chow Adult	NA	21.0%	8.0%	yellow corn	soybean meal	meat/bone meal	BHA		
Ralston Purina Pro Plan	Adult	1900	25.0%	15.0%	chicken	brewers rice	wheat	Ethoxyquin		
	Performance	1971	30.0%	20.0%	chicken	corn gluten	brewers rice	Ethoxyquin		
	Turkey/Barley	1796	25.0%	15.0%	turkey	barley	corn	Vitamin E		
Sensible Choice	Adult	1695	25.0%	12.0%	lamb meal	brewers rice	rice flour	Tocopherols		
	High Performance	1912	30.0%	20.0%	lamb meal	brewers rice	poultry fat	Tocopherols		
Solid Gold	Hund-N-Flocken	1800	22.0%	8.0%	lamb meal	whole ground millet	brown rice			
Star Milling Co.	Premium Dog	1604	27.0%	15.0%	poultry meal by-product	ground wheat	meat & bone bone meal	Propionic Acid		
Sunshine Mills	Gravy Delight	NA	21.0%	8.0%	yellow corn	soybean meal	meat & bone meal	BHA		
United Pacific Mills	Good Life Meat Based	NA	25.0%	10.0%	meat meal	ground yellow corn	ground wheat			
Walter Kendall	Premium Kibble	NA	20.0%	8.0%	whole wheat	meat/bone meal	ground rice	Tocopherols		

NA = information not available, or not obtained before publication deadline

The question boils down simply to this: What commercial food should I feed my dog? The answer is much less simple. To make this point clearly before proceeding further, examine photograph 1 in comparison to photograph 2. The same Akita bitch is shown in both photographs. In the first, she was a fed lamb and

rice and a lamb and rice and barley feed, both without ethoxyquin. Flea season had hit and we thought we would make it easier for her by feeding a hypoallergenic diet. While I generally advocate avoiding foods preserved with ethoxyquin, I feel it is only fair to mention that photograph 2 is the same animal on Iams Eukanuba Original with ethoxyquin. This is just one case of many where one dog does well on one food but poorly on another regardless of what rules you might read. Nutritional rules of thumb are but general rules.

Table 2
Relative ME Energy Requirements

Physiological State	Adult = 1.0 (NRC-74)
Weaning	
Start (3 weeks)	3.0
Finish (6 weeks)	2.8
Growth	
Early Growth	2.7
Half Grown	1.7
Adult States	
Adult Maintenance	1.0
Pregnancy (late)	1.7
Lactation	4.2

Table 3
Changes in Energy Requirements for a 20-kilogram Husky in harness

Type of Exercise	Energy Requirements (kcal of ME)	Activity Factor
Maintenance	1,000-1,200	1.0
Training		
2-5 mi/day	1,300-1,400	1.2
6-12 mi/day	1,700-1,800	1.5
19 mi/day	2,000-2,400	2.0
Speed Racing	1,400-1,800	1.5
Long Distance		
Alpirod	2,500-3,000	2.5
Iditarod	7,000-8,000	6.7

Adapted from Grandjean and Paragon: "Nutrition of Racing and Working Dogs," Part II.

The list of definitions charts the nutritional ingredients I found listed on dog food labels. They are probably illustrative of what you will find on the labels of the foods you are feeding now. Be aware that a label may list a meat or meat product first, followed by separate cereal grains. More often than not, such a food should be viewed as a cereal food and not a meat-based food. For example, a food label listing in order of weight: chicken, wheat, soy, corn and rice, might have the following percentages by weight: chicken—21 percent, wheat—20 percent, soy—20 percent, corn—20 percent, rice—10 percent. This is not a "chicken-based" product. It is a cereal-based product with a ratio of cereal to chicken of 70:21 or 3.3:1. There is no way to tell from the labeling or from the advertising. When wet weights are compared to dry weights, wet weights win—compare the weight of a soggy wet bath towel to a dry one.

Another common way of labeling is to break a particular ingredient down into its parts. For example: ground yellow corn, corn gluten, corn meal. This corn-based cereal dog food can be labeled and advertised as a potent meat-, chicken- or lamb-based food fit for the most voracious of carnivores by adding just enough meat to the corn mush to bump the corn ingredients to second place in the list. There is no way to find this out from the label. Some manufacturers are using this to attack each other.

Manufacturers, through lobbying and creating fine-sounding councils providing technical assistance to the United States Department of Agriculture, Food and Drug Administration and anyone who would listen, have managed over the years to build up a belief system which is difficult to challenge because of its longevity. The real message is clear, and it is in print, but it has not made it all the way to the dog food-buying public. Hear the less-than-comfortable words of Randy Wysong, D.V.M. He takes issue with the advertising of a 100 percent nutritionally complete dog food, especially if the claim is extended to include all biological phases of a dog's life. "Thus, that which is absurd in human nutrition has become commonplace, expected and even mandated in pet nutrition." He contends dangers of the 100 percent complete concept include:

• Ignores individuality—"Within a species, lysine requirements may vary seven-fold; certain other amino acids, nine-fold; enzyme levels, 50-fold; vitamin A, 40-fold; vitamin C, 100-fold. . . . Biochemical individuality is nevertheless real and a formidable obstacle to ever applying statistical averages to all members of a population."[4] This should give you greater insight into why a given animal may do well on one dog food and poorly on the foods that cause the rest of your dogs to thrive.

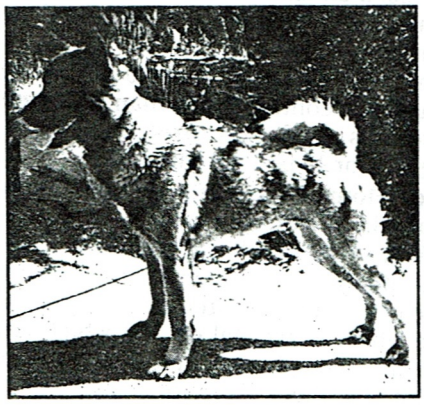
• False statement—"We don't have complete knowledge of what nutrients a pet requires." Therefore, how can a manufacturer state with any certainty that its products are 100 percent complete?

• Processing dangers—"Processing can decrease nutrient content and bioavailability and create new toxic compounds that are potentially carcinogenic, mutagenic, atherogenic and free radical-generating." (Gregory 1989, Lowry 1989, Wysong, 1989.)

• False sense of security—"Allowing the '100 percent complete' claim gives consumers a false impression that regulators can guarantee quality. They cannot."[5]

• Digestibility—Dr. Wysong's turn of a phrase is one of the best I have ever heard or read: "Nutrition is a tissue-level biochemical phenomenon, not a simple subtraction between what is eaten and what is excreted. *We are not what we eat, rather we are what our tissues utilize.*"

It is important not to get caught up in the advertising hype concern-



Photograph 1.

Photograph 2.

ing digestibility. "Does 95 percent digestibility of a food mean the food is better than a 90 percent digestible food or an 85 percent digestible food? If so, then would that mean that a 98 percent digestible or a 100 percent digestible food should be the goal of nutritional science? Isn't the logical conclusion of digestibility measurements that 100 percent digestibility, or zero fecal output, is the optimal diet? This is reductio ad absurdum. Gastrointestinal health, on the contrary, depends upon the passage of a certain volume of food—and often the greater the volume, the better the health (Vahonny, 1985)."[6,7]

Dog foods vary extremely in their content and their potency or metabolizable energy per unit of weight. It is imperative to match the dog food to the individual dog, especially in the following areas:

(a.) ME requirements based upon the dog's weight. See Figures 1 through 5 in "Feed that dog! Part I."[8]

(b.) ME requirements based upon activity level. See Table 3. This example is for illustration only, as Huskies have lower maintenance energy requirements than do other dogs (100 to 110 kcal ME/kg body weight$^{0.75}$ compared with the NRC estimated 132 kcal ME/kg body weight$^{0.75}$).[9] Similarly, in general terms for other dogs used in field trials, shows, etc., you can expect "an approximate 10 percent increase in maintenance energy requirements. Thus a 40 percent to 50 percent increase in energy intake is necessary for one day of work or sport."[10]

(c.) ME requirements based upon thermoregulation (heat regulation). McNamara estimates 3 kcal ME/kg body weight$^{0.75}$ for each degree Celsius below 20 degrees.[11]

(d.) Allergies. Like people, dogs can be allergic to just about anything. Common allergies are: soy, dairy products, food additives and preservatives.

(e.) Biological stage: growing puppy, lactating bitch, adult, geriatric. See Table 2.

(f.) Energy availability and gastrointestinal utilization. Racing, working and hunting dogs' levels of exercise alter gastrointestinal motility by reducing gastrointestinal transit time, often resulting in diarrhea. Short transit times require rapid digestibility. Starches, for instance, compared with fats are more bulky. Grandjean and Paragon say: "Even a small increase in the volume ingested, however, results in lowered digestibility and wetter feces, which can lead to diarrhea."[12]

It is important to recognize that AAFCO requires a minimum testing protocol to support claims of nutritional adequacy. For example: "Minimum Testing Protocol for Proving a Gestation/Lactation Claim for a Dog Food" requires that a minimum of six bitches be used for the test, which lasts from first signs of heat to when the puppies are fully weaned at 6 to 8 weeks of age.[13]

Interpretation of the results: Two-thirds of the pregnant bitches stated on the test must have shown weight gain during gestation. "One week after whelping, the body weight should return to the original beginning test weight. Maximum deviation permitted is minus 10 percent. At weaning, the original beginning test weight of each bitch is desired. Maximum deviation permitted is minus 15 percent."[14] Furthermore, the bitch "must wean at least 75 percent of her one-day-old pups" and "the average weight of pups shall, as a minimum, equal the growth curve of puppies in normal ranges for the breed.[15] Similarly, the protocol for testing adult foods requires six dogs, of any size, any sex, with a test period of not less than 26 weeks. "Weight loss in excess of 15 percent individually, or 10 percent as a group, shall constitute a test failure."[16]

These testing protocols have gone a long way toward standardizing the nutritional qualities of manufactured foods; however, one should remember that the animals used tend to be colony Beagles under little or no stress, and with little individual variance. As I look over the dogs I have now and the dogs that I have had, I recognize that Kiku and K.J., Ka-aba and Kaizen will always be fat girls on standard rations, and therefore forever on a diet. Yukon never held weight without extra food. K.O., regardless of what he was fed, would lose weight when bitches were in season—he worried it off. Others were right on when fed a standard ration, but lost weight on the show circuit. One last crucial point to remember: Not all dogs will do well on a standard ration of any given food; experimentation with several brands may be in order.

Labels provide an incomplete picture of dog food contents, but taken within the context of their meaning, labels provide a starting point. You should take away from this article that individual dogs have unique dietary requirements based upon their biological stage of life, thermoregulation, exercise and stress requirements. The charts contained in Part I provide only a starting point from which to make caloric adjustments. The most useful measurement is personal observation as to whether a given animal is at a good weight or not. With respect to quality of ingredients and cost, we must remember that until we are willing to pay as much for dog food as we do for human food, and accept short shelf lives, there will continue to be a lot of preservatives and lower-quality ingredients. Coming from the perspective of having Akitas, I would hate to spend as much per month on dog food for a 125-pound active dog as one would for a 14-year-old son.

AAFCO definitions of dog food ingredients

Alfalfa Meal—the aerial portion of the alfalfa plant, reasonably free from other crop plants, weeds and mold, which has been sun-cured and finely ground.

Animal Digest—material which results from chemical and/or enzymatic hydrolysis of clean and undecomposed animal tissue. The animal tissues used shall be exclusive of hair, horns, teeth, hooves and feathers, except in such trace amounts as might occur unavoidably in good factory practice and shall be suitable for animal feed.

Animal Fat—is obtained from the tissues of mammals and/or poultry in the commercial processes of rendering or extracting. It consists predominantly of glyceride esters of fatty acids and contains no additions of free fatty acids. If an antioxidant is used, the common name or names must be indicated, followed by the words "used as a preservative."

Barley—consists of at least 80 percent sound barley and must not contain more than 3 percent heat-damaged kernels, 6 percent foreign material, 20 percent other grains or 10 percent wild oats.

Barley Flour—soft, finely ground and bolted barley meal obtained from the milling of barley. It consists essentially of the starch and gluten of the endosperm.

Beef (Meat)—is the clean flesh derived from slaughtered cattle, and is limited to that part of the striate muscle which is skeletal or that which is found in the tongue, in the diaphragm, in the heart, or in the esophagus; with or without the accompanying and overlying fat and the portions of the skin, sinew, nerve and blood ves-

sels which normally accompany the flesh.

Beet Pulp ("Beet pulp, dried molasses" and "beet pulp, dried, plain")—the dried residue from sugar beets.

Brewer's Rice—the dried extracted residue of rice resulting from the manufacture of wort (liquid portion of malted grain) or beer and may contain pulverized dried spent hops in an amount not to exceed 3 percent.

Brown Rice—unpolished rice after the kernels have been removed. Not a complete AAFCO definition.

Carrots—presumably carrots. No AAFCO definition.

Chicken—the clean combination of flesh and skin with or without accompanying bone, derived from the parts or whole carcasses of chicken or a combination thereof, exclusive of feathers, heads, feet and entrails.

Chicken Byproduct Meal—consists of the ground, rendered, clean parts of the carcass of slaughtered chicken, such as necks, feet, undeveloped eggs and intestines, exclusive of feathers, except in such amounts as might occur unavoidably in good processing practices.

Chicken Liver Meal—chicken livers which have been ground or otherwise reduced in particle size.

Chicken Meal—chicken which has been ground or otherwise reduced in particle size.

Corn—unspecified corn product. Not a complete AAFCO definition.

Corn Bran—the outer coating of the corn kernel, with little or none of the starchy part of the germ.

Corn Germ Meal (Dry Milled)—ground corn germ which consists of corn germ with other parts of the corn kernel from which part of the oil has been removed and is the product obtained in the dry milling process of manufacture of corn meal, corn grits, hominy feed and other corn products.

Corn Gluten—that part of the commercial shelled corn that remains after the extraction of the larger portion of the starch, gluten, and term by the processes employed in the wet milling manufacture of corn starch or syrup.

Corn Gluten Meal—the dried residue from corn after the removal of the larger part of the starch and germ, and the separation of the bran by the process employed in the wet milling manufacture of corn starch or syrup, or by enzymatic treatment of the endosperm.

Corn Syrup—concentrated juice derived from corn.

Cracked Pearl Barley—cracked pearl barley resulting from the manufacture of pearl barley from clean barley.

Dehydrated Eggs—dried whole poultry eggs freed of moisture by thermal means.

Digest of Beef—material from beef which results from chemical and/or enzymatic hydrolysis of clean and undecomposed tissue. The tissues used shall be exclusive of hair, horns, teeth and hooves, except in such trace amounts as might occur unavoidably in good factory practice.

Digest of Beef Byproducts—material from beef which results from chemical and/or enzymatic hydrolysis of clean and undecomposed tissue from non-rendered clean parts, other than meat, from cattle which includes, but is not limited to, lungs, spleen, kidneys, brain, livers, blood, bone, partially defatted low-temperature fatty tissue, and stomachs and intestines freed of their contents. It does not include hair, horns, teeth and hoofs.

Digest of Poultry Byproducts—material which results from chemical and/or enzymatic hydrolysis of clean and undecomposed tissue from non-rendered clean parts of carcasses of slaughtered poultry such as heads, feet, viscera, free from fecal content and foreign matter except in such trace amounts as might occur unavoidably in good factory practice.

Dried Animal Digest—dried material resulting from chemical and/or enzymatic hydrolysis of clean and undecomposed animal tissue. The animal tissue used shall be exclusive of hair, horns, teeth, hooves and feathers, except in such trace amounts as might occur unavoidably in good factory practice and shall be suitable for animal feed. If it bears a name descriptive of its kind or flavor(s), it must correspond thereto.

Dried Kelp—dried seaweed of the families Laminaricae and Fu-caeae. If the product is prepared by artificial drying, it may be called "dehydrated kelp."

Dried Milk Protein—obtained by drying the coagulated protein residue resulting from the controlled co-precipitation of casein, lactalbumin and minor milk proteins from defatted milk.

Dried Reduced Lactose Whey—no AAFCO definition available.

Dried Whey—the product obtained by removing water from the whey. It contains not less than 11 percent protein nor less than 61 percent lactose.

Feeding Oatmeal—obtained in the manufacture of rolled oat groats or rolled oats and consists of broken oat groats, oat groat chips, and floury portions of the oat groats, with only such quantity of finely ground oat hulls as is unavoidable in the usual process of commercial milling. It must not contain more than 4 percent crude fiber.

Fish Meal—the clean, dried, ground tissue of undecomposed whole fish or fish cuttings, either or both, with or without the extraction of part of the oil.

Ground Corn—(ground ear corn) the entire ear of corn ground, without husks, with no greater portion of cob than occurs in the ear corn in its natural state.

Ground Dehulled Oats—presumably ground cleaned oats with hulls removed (ground oat groats). Not an AAFCO definition.

Ground Wheat—presumably a coarser grind of wheat flour. Not an AAFCO definition.

Ground Whole Brown Rice (Ground Brown Rice)—the entire product obtained by grinding the rice kernels after the hulls have been removed.

Ground Whole Wheat—ground whole kernel, presumably equivalent to AAFCO's Wheat Mill Run, Wheat Middlings, Wheat Shorts or Wheat Red Dog, whose principal differences are in the percentage of crude fiber.

Ground Yellow Corn—same as ground corn, except that the corn used is yellow in color.

Kibbled Corn—obtained by cooking cracked corn under steam pressure and extruding from an expeller or other mechanical pressure device.

Lamb Bone Meal—(steamed) dried and ground product sterilized by cooking undecomposed bones with steam under pressure. Grease, gelatin and meat fiber may or may not be removed.

Lamb Digest—material resulting from chemical and/or enzymatic hydrolysis of clean and undecomposed lamb. The tissue used shall be exclusive of hair, horns, teeth and hooves, except in such trace amounts as might occur unavoidably in good factory practice and shall be suitable for animal feed.

Lamb Fat—obtained from the tissues of lamb in the commercial processes of rendering or extracting. It consists predominantly of glyceride esters of fatty acids and contains no additions of free fatty acids. If an antioxidant is used, the common name or names must be indi-

cated, followed by the words "used as a preservative."

Lamb Meal—the rendered product from lamb tissues, exclusive of blood, hair, hoof, horn, hide trimmings, manure, stomach and rumen contents except in such amounts as may occur unavoidably in good processing practices.

Linseed Meal—the product obtained by grinding the cake or chips which remain after removal of most of the oil from flaxseed by a mechanical extraction process. It must contain no more than 10 percent fiber. The words "mechanical extracted" are not required when listing as an ingredient in a manufactured food.

Liver—the hepatic gland (of whatever species is listed).

Meat and Bone Meal—the rendered product from mammal tissues, including bone, exclusive of blood, hair, hoof, horn, hide trimmings, manure, stomach and rumen contents, except in such amounts as may occur unavoidably in good processing practices.

Meat Byproducts—the non-rendered, clean parts, other than meat, derived from slaughtered mammals. It includes, but is not limited to, lungs, spleen, kidneys, brain, livers, blood, bone, partially defatted low-temperature fatty tissue and stomachs and intestines freed of their contents. It does not include hair, horns, teeth and hoofs.

Meat Meal—the rendered product from mammal tissues, exclusive of blood, hair, hoof, horn, hide trimmings, manure, stomach and rumen contents except in such amounts as may occur unavoidably in good processing practices.

Peas—peas.

Potatoes—potatoes.

Poultry Byproduct Meal—consists of the ground, rendered, clean parts of the carcass of slaughtered poultry, such as necks, feet, undeveloped eggs, intestines, exclusive of feathers, except in such amounts as might occur unavoidably in good processing practices.

Poultry Byproducts—consist of non-rendered clean parts of carcasses of slaughtered poultry such as heads, feet and viscera, free from fecal content and foreign matter except in such trace amounts as might occur unavoidably in good factory practice.

Poultry Digest—material which results from chemical and/or enzymatic hydrolysis of clean and undecomposed poultry tissue.

Poultry Fat (feed grade)—primarily obtained from the tissue of poultry in the commercial process of rendering or extracting. It shall contain only the fatty matter natural to the product produced under good manufacturing practices and shall contain no added free fatty acids or other materials obtained from fat. It must contain not less than 90 percent total fatty acids and not more than 3 percent of unsaponifiables and impurities. It shall have a minimum titer of 33 degrees Celsius. If an antioxidant is used, the common name or names must be indicated, followed by the word "preservative(s)."

Powdered Cellulose—purified, mechanically disintegrated cellulose prepared by processing alpha cellulose obtained as a pulp from fibrous plant materials. (Author's note: sawdust.)

Rice Bran—the pericarp or bran layer and germ of the rice, with only such quantity of hull fragments, chipped, broken, or brewer's rice, and calcium carbonate as is unavoidable in the regular milling of edible rice.

Rice Flour.

Soy Flour.

Soybean Hulls—consist primarily of the outer covering of the soybean.

Soybean Meal (Dehulled, Solvent Extracted)—obtained by grinding the flakes remaining after removal of most of the oil from dehulled soybeans by a solvent extraction process.

Soybean Meal (Mechanical Extracted)—obtained by grinding the cake or chips which remain after removal of most of the oil from the soybeans by a mechanical extraction process.

Soybean Mill Run—composed of soybean hulls and such bean meats that adhere to the hulls which results from normal milling operations in the production of dehulled soybean meal.

Tallow—animal fats with titer above 40 degrees Celsius.

Turkey—unspecified turkey. Not a complete AAFCO description.

Turkey Meal—the ground clean combination of flesh and skin with or without accompanying bone, derived from the parts or whole carcasses of turkey or a combination thereof, exclusive of feathers, heads, feet and entrails.

Wheat Bran—the course outer covering of the wheat kernel as separated from cleaned and scoured wheat in the usual process of commercial milling.

Wheat Flour—wheat flour together with fine particles of wheat bran, wheat germ and the offal from the "tail of the mill." This product must be obtained in the usual process of commercial milling and must not contain more than 1.5 percent crude fiber.

Wheat Germ Meal—consists chiefly of wheat germ together with some bran and middlings or short. It must contain not less than 25 percent crude protein and 7 percent crude fat.

Wheat Mill Run—coarse wheat bran, fine particles of wheat bran, wheat shorts, wheat germ, wheat flour and the offal from the "tail of the mill." This product must be obtained in the usual process of commercial milling and must contain not more than 9.5 percent crude fiber.

Whey—the product obtained as a fluid by separating the coagulum from milk, cream or skimmed milk and from which a portion of the milk fat may have been removed. (Author's note—the watery part of milk separated from the curd.)

References:

1. American Association of Feed Control Officials, "Official Publication," 1990, p. 83.
2. Cargill, J.C.; "Feed that dog! Part II," DOG WORLD, August 1993, pp. 10-16.
3. "Official," p. 83.
4. Ibid., p. 46.
5. Ibid.
6. Ibid.
7. Ibid.
8. Cargill, J.C.; "Feed that dog! Part I." DOG WORLD, July 1993, pp. 24-25.
9. Grandjean, D., Paragon, B.M. "Nutrition of Racing and Working Dogs. Part II," *Compendium*, January 1993, Vol. 15, No. 1, p. 46.
10. "Nutrition," p. 47.
11. McNamara, J.H., "Nutrition for Military Dogs Working Under Stress," *Veterinary Medicine Strategic Air Command,* 1972; Vol. 67, pp. 615-623.
12. "Nutrition," p. 48.
13. "Official," p. 89.
14. Ibid., p. 89.
15. Ibid., p. 90.
16. Ibid., p. 91.

Part IV

The authors explain the chemical structures of natural and synthetic antioxidants and their use in preserving dog foods

In this part, Susan Thorpe-Vargas, a biochemist and doctoral candidate, joins me in presenting the various issues involving the antioxidants used in preserving dog foods. Conclusions from "Feed that dog! Part III" (September 1993 issue): Some labels provide an incomplete and possibly misleading picture of dog food contents. Individual dogs have unique dietary requirements based upon their biological stage of life, thermoregulation, exercise and stress requirements. The charts contained in Part I provide only a starting point from which to make caloric adjustments. The most useful measurement is personal observation of whether an animal is at a good weight.

The previous articles have raised the question of whether commercial dog foods are a good buy. In Part I biologic values of various ingredients were discussed. In Part III, some labeling practices were shown to be misleading. Some common ingredients are questionable. The fact remains that you get what you pay for. You get the ingredients you pay for; you get the distribution system you pay for. In the name of convenience and cost, most of us feed our dogs what happens to be available on the market.

Few of us can afford to feed our dogs as if we had just gained a new member of the family, especially those of us with multiple dogs. One well-known dog food manufacturer has suggested that a 40-pound bag would cost about $245 if it contained those lovely lamb chops, whole chickens, eggs and the other assorted pristine ingredients shown on the label.[1] Similarly, the dog food would have to be distributed to outlets with a high turnover. Even with refrigeration, it would last no longer than your next bottle of milk. So, are we agreed that some compromise has to be made concerning the quality of the food and byproducts used to produce dog food? Certainly, Susan and I are agreed; we cannot even begin to pay for feeding our respective kennels of Akitas and Samoyeds the quality of food we eat.

Dog food manufacturers, like their human food counterparts, are in the business to make money. No corporation would stay in business very long if it did not make a profit. The profit margin is the difference between what manufacturers sell their products for, minus the cost of goods and the cost of doing business. However, the cost engendered by production has multiple factors, not the least of which is raw materials and product shelf life. Product shelf life in foodstuffs translates directly into profit, hence the need for some form of preservation. Preserved foodstuffs require less care and maintenance in distribution and presentation for sale. Preservation is therefore directly related to reduced product costs and profit. Even as Coors beer manufacturing company has found out, it is difficult to attempt to insist on refrigerated shipping, storage and presentation to the public.

As mentioned in Part I, fats are one of the most important components of a healthy diet and are the most compact of energy sources, yielding 8.46 kcal/g. Performance and working dog feeds are characteristically high in fat content, especially for those dogs who find themselves working in cold weather.

The concepts following are simple in their general application, but very difficult in the specific. Dietary fats and their metabolic products are required for many vital processes. Fats and their metabolic products are the main constituents of the cell membrane (the envelope that separates one cell from another). They serve as precursors in the synthesis of hormones and are necessary for the uptake of fat-soluble vitamins. Lipids (another name for fats) are also instrumental in regulating cell metabolism. They can be used as a source of "condensed" energy, or stored in either muscle cells or adipose tissues. (A pound of stored fat yields about 3,500 kcals as compared to the 1,500 kcals for an equivalent amount of protein or carbohydrate provides.)[2]

The slowest form of oxidation is rusting, and since we live in an oxygen atmosphere, everything is subject to oxidation. Fats are particularly vulnerable to oxidation because they contain multiple double bonds (carbon linked twice to another carbon). For some reason these are especially reactive sites. To prevent rancidity, one has to prevent oxidation and free-radical generation. This is the function performed by antioxidants. Fats, also known as fatty acids, are also the most vulnerable dietary component to chemical breakdown; this, in turn, leads to a dangerous and potentially toxic condition called rancidity. Besides depleting the body's vitamin E, C and beta-carotene, the greatest danger from rancid fat is free radical formation. Also, the breakdown products include aldehydes and ketones. These products contribute to the "off" smell and taste, but are relatively benign, as they are metabolized like sugar. One of these, however, malondialdehyde, is mutagenic, as it promotes cross-linking of proteins and DNA.[3] This is not good.

Oxygen in the atmosphere exists in the diatomic state. One atom of oxygen is linked, or "bonded," to another atom of oxygen to make a molecule of oxygen. The molecule likes to be in this state, as it is at its lowest energy level. Normally, each atom of the oxygen molecule contains four pairs of electrons. Two pairs are "co-owned" by both of the atoms—in other words, they share two pairs of electrons. Certain metabolic and

Chart 1

Relative efficacies of antioxidants

Half-life of beta carotene mixed with oxidized linoleic acid with and without antioxidants

Antioxidant	Beta carotene half-life (min.)
None	42.5
BHA	55.9
BHT	63.6
Ethoxyquin	261.5

Chart 2

Safe levels of ethoxyquin

Species	mg/kg/day	Approximate PPM
Steers	0.77	25
Swine	1.50	38
Sheep	3.78	95
Dogs	3.00	See note

From FDA internal memo dated April 8, 1955.
Note: Mg/Kg/Day varies with estimate of weight of animal and how much feed is ingested.

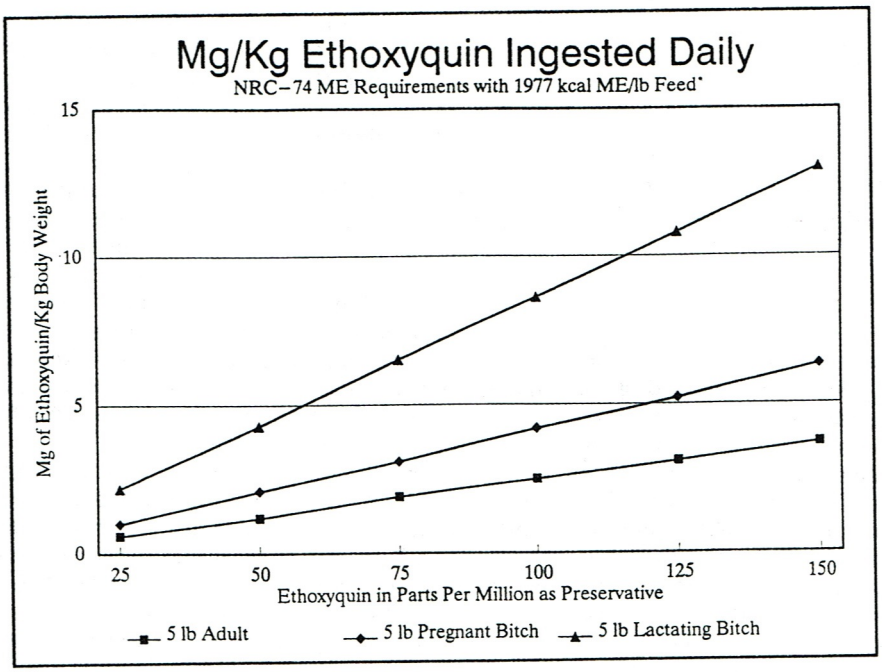


Chart 3

chemical processes can rob these atoms of an electron, thus producing a free radical. Each free radical can then start its own chain reaction. This process can be visualized by the dropping of a pingpong ball onto a surface covered with hundreds of mousetraps "baited" with pingpong balls. One of the causes of lameness and arthritis in old dogs is thought by some to be a function of free radicals destroying the lipid and protein constituents of synovial fluid in joint spaces.[4]

Dog food manufacturers have a choice of which antioxidants to use. The "natural" forms consist of a modified form of vitamin E, linked with vitamin C. The synthetic forms include BHA (butylated hydroxyanisole), BHT (butylated hydroxytoluene) and ethoxyquin. These antioxidants function by means of a molecular structure that gives up an electron to a free radical without themselves becoming harmful, thus stopping the chain reaction that damages cellular components and membranes. A comparison of the relative efficacies of the synthetic antioxidants is made in Chart 1.

Vitamins C (ascorbic acid) and E (alpha-tocopherols) are natural antioxidants. Remember, antioxidants function by donating an electron to a free radical, which stops the chain reaction.

Lipid peroxide + vitamin E → oxidized vitamin E.

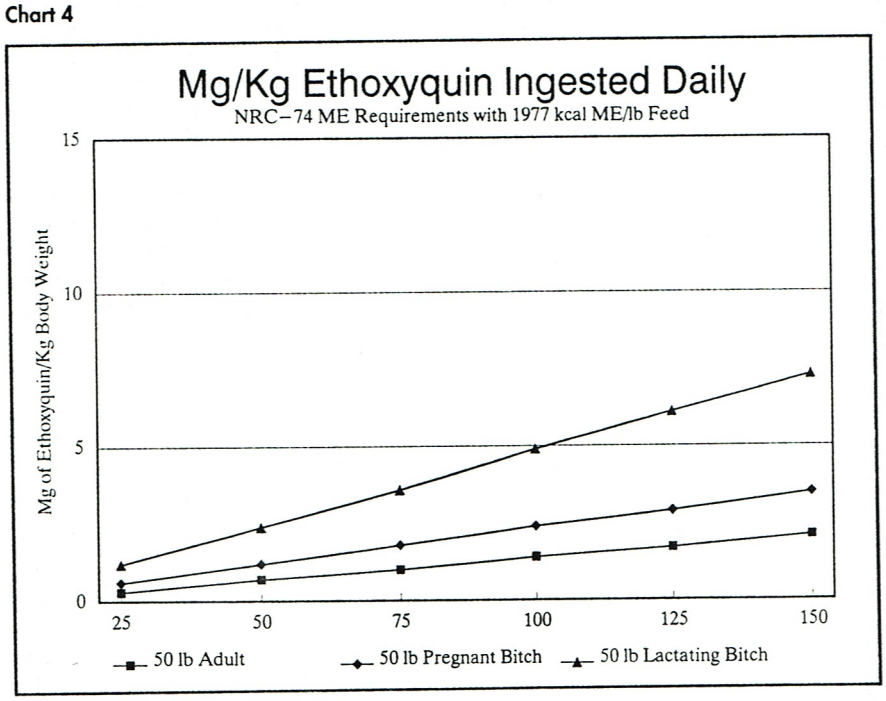
Comparing the structures of both vitamin E and ethoxyquin, one notices that vitamin E has a long side chain. This "fatty" tail is very important because it allows vitamin E to slip easily inside cell membranes. Researchers in England report vitamin E physically stabilizes the membrane, making it stronger and more impervious to perturbations.[5,6]

Cheeke and Shull (1972) found that vitamin E may have another metabolic role other than as a membrane-bound antioxidant. Several studies seem to support this. Their paper on hindered growth in vitamin E-deficient rats demonstrated that synthetic antioxidants were unable to restore normal growth—only vitamin E was productive.[7] Riis et al. (1981), in a study on retinopathy (a non-inflammatory disease of the retina) in dogs, showed that neither ethoxyquin nor 10 times the NRC-recommended amount of selenium induced beneficial ophthalmological changes; only vitamin E did.[8] Several recent journal articles claim the combination of vitamins E and C prevents changes in low-density lipoproteins (the bad cholesterol) that leads to hardening of the arteries.[9]

Vitamin E and vitamin C are generally preferable to the synthetic antioxidants because they have no adverse effects, and they seem to have beneficial properties in addition to their antioxidant function. Vitamins E and C are quite adequate to preserve dog food if and only if the distribution system has suitable storage and a high turnover.

BHA and BHT are two synthetic antioxidants that have been used as preservatives for several decades, not only in dog food but also extensively in the human diet. Check out your bread label sometime. Long considered a safe alternative, there have been research articles published in the past couple of years that indicate that BHA and BHT usage can be deleterious, especially BHT usage. It is not the chemicals themselves that seem to be causing the problems, but rather the "in vivo" (within a living system) breakdown products. In the process of metabolizing BHA and BHT, chemical changes occur in the body and it is these metabolites which are thought to be harmful.[10] Concentration (how much antioxidant per gram) and the age of the animal eating the sub-

Chart 4



stance appear to be significant.

One effect of BHA/BHT is inhibition of lymphocyte stimulation (white blood cells involved in the immune response). Another effect is induction of cell proliferation in several organs, including the bladder, kidney and liver.[11] For example, in the lungs, BHT promotes the expression of the PAH (pulmonary adenoma histogenesis) genes, which promotes lung cancer.[12] The antioxidants—BHA and BHT—also uncouple the electron transport system. This is significant. ATP (adenine triphosphate) may be thought of as a type of "banker." The body "deposits" energy derived from the breakdown of food and "withdraws" the energy when it needs to make new cellular components like proteins, lipids (fats) and complex carbohydrates. The breakdown of each glucose molecule (the Citric Acid Cycle) and the Electron Transport System account for the net production of 32 ATP molecules. An impaired glucose uptake would seriously compromise an animal's energy production abilities.

Most ATP production occurs in the cell membrane of the mitochondria. Mitochondria are actually cells within cells. Within the cell, electrons are passed down an electro-chemical gradient until accepted by oxygen and released as water. During this process ATP is reconstituted from ADP (adenine diphosphate). BHT increases cell membrane permeability and the cells become "leaky." Thus, their function of maintaining a concentration gradient is impaired. When ionic species (the cation and the anion) are separated by a cell membrane there is a potential energy difference. This potential energy can be used to transport stuff in and out of cells. BHT hinders this process and thus disrupts the production of ATP.[13]

(Both atoms and molecules exist in what are called electronic "states." This refers to how many electrons (which are negative) are balanced by the positive component of the nucleus (the proton). If an atom or a molecule is carrying a "net" negative or positive charge, it is called an ion. If the charge is positive, that means the ion has more protons then electrons and it is called a cation. If the charge is negative, then it has more electrons then protons and is called an anion. When a molecule gains an electron it has been "reduced" and when it loses an electron it has been "oxidized.")

BHT also combines with another chemical called glutathione, which increases its toxicity.[14] The two chemicals are synergistic: The effect of one is increased by the presence of the other. In conclusion, it has been shown that BHT significantly increases lipoperoxide production.[15] BHA specifically reduces glutathione peroxidase activity.[16] This is rather ironic, as this is what antioxidants are hoped to prevent.

In the late 1950s a special amendment to the Food, Drug and Cosmetic Act was passed, and the first substance approved under its aegis was ethoxyquin. Before its approval, the Food and Drug Administration characterized it as a poison with a very narrow toxicity range. This means that even a slight overdose can become quickly lethal.

"We have already recognized (the) propriety of animal treatment with poisons which promote physiological changes of an economic importance. . . . I see no great difference between that and use of poisons which foster the nutrition of animals. Risk of untoward consequences to the animals themselves is of an economic nature. . . . " Internal memo, FDA, April 13, 1955, Frank A. Vorhees Jr. to R. Roe, Assistant Commissioner, FDA.

No long-term dog studies were done to ascertain the safety or efficacy of the product. The only studies done were those contracted by the manufacturer to establish the permissible exposure limits for humans working with the chemical (known as Material Safety Data) and to verify metabolic fade out or how long the substance stays in the tissues of animals intended for human consumption. This information was required before the FDA would approve ethoxyquin's use in animal feedstock. These studies, a one- and five-year analysis, were seriously flawed; most significant was the complete mix-up between the control and the experimental animals during the five-year study. When this happened, the experimental data became null and void by modern criteria, and yet the FDA chose to accept the data. Based on the information gained from these "studies," the FDA approved its use at 150 ppm (parts per million) on the finished product.

Note that ethoxyquin toxicity varies significantly between species. Chart 2 details the "safe" amounts allowed to be added to feeds for common domestic species. Charts 3 and 4 detail the amounts of ethoxyquin ingested while feeding a 1,977 kcal ME/pound dry dog food at NRC-74 rates to a 5-pound dog in various biological stages and a 50-pound dog, respectively. It is important to realize that the FDA established safe levels for dogs at 3 mg/kg/day and toxic levels at 10 mg/kg/day. That 3 mg/kg/day safe level equates to a 30-pound adult dog fed 1,977 kcal ME dog food laced with no more than 90 parts per million ethoxyquin. Given the flaws in the studies and the fact that ethoxyquin was fed only five days out of seven, allowing the kidneys and liver to regenerate, one can make an easy case that the safety and toxic levels established are significantly above what could be demonstrated scientifically.

Since its inclusion in the diet of house pets, both "pet people" and breeders have experienced problems. Anecdotal stories have been exchanged at dog shows, in newsletters, breed magazines and over the back fence. Clinically, the dogs have presented such diverse symptoms as an increased incidence of cataracts and periodontal disease, depressed immune response (vaccine failure and infectious conditions), precancerous lesions of the liver, kidney and bladder, hemolytic anemia, skin and coat problems, decreased fertility, sterility and testicular atrophy, teratogenesis (puppies with gross birth defects) and muscular weakness.

Could a single chemical be causing such widely divergent symptoms? Why do some dogs seem to thrive on foods that contain the antioxidant while others exhibit such untoward effects? Various authors have claimed they are unable to find any scientific evidence to support the breeders' complaints. However, a myriad of scientific and medical data bases, available at most universities, contain a plethora of evidence that ethoxyquin is hardly benign. Proponents point out that ethoxyquin has been present in feedstocks for more than 30 years, but it has only been used in dog foods for the last decade or so. Ethoxyquin's original approved use was as a grain preservative on feed intended for animals raised for slaughter that would live no longer then two years at best. How it came to be approved for domestic pets that live on the average 10 years or more is anybody's guess. Currently, there is a petition on the FDA agenda to prohibit use of ethoxyquin in dog foods.[17]

One ethoxyquin study we found while roaming the data bases comes from Norway (Skaare, 1976) and shows that ethoxyquin inhibits the uptake of glucose

from the intestine and at very small concentrations can reverse "mediated" transport of glucose so that it is taken out of the blood and dumped into the gut.[18,19]

Glucose is a "simple" sugar, also known as a monosaccharide. Most carbohydrates are chains of monosaccharides and the body has enzymes which break these chains into their simpler components so that the body can make use of their nutrition. Glucose's structure is unusual. It is composed of a ring containing six carbons like the other hexoses (hex-, for six). Of all the other simple sugars, it is the only one in which all the atoms attached to the ring structure lie in the same plane. Because of this singular three-dimensional orientation in space, the enzymes contained within the cell membranes that transport glucose out of the intestine and into the bloodstream are especially vulnerable to distortion. The lock no longer "fits" the key, so to speak. This has grave consequences for the animal, because the major metabolic pathways of carbohydrate metabolism either begin or end with glucose. Not only is glucose the major form in which carbohydrates coming from the intestinal tract are presented to the rest of the body, it is the primary fuel used by the brain. Glucose's most important function, though, is its role in the synthesis of ATP (adenine triphosphate).

Another very serious consequence to a restricted glucose absorption system is specific to red blood cells. The metabolic pathway affected is the Pentose Phosphate system, and its function is to keep another important molecule, NADPH, "reduced." NADPH is necessary for carrying electrons to an enzyme called glutathione peroxidase. Glutathione's purpose is to keep free radicals and peroxides from damaging DNA, cell membranes and other cellular elements.

A study from the Tufts' Center On Aging revealed that ethoxyquin reduced the blood plasma level of the most active form of vitamin E by 42 percent, with a paradoxical corresponding drop in Prostaglandin E_2 synthesis.[20] Prostaglandins are effective in minute concentrations and are necessary in anti-inflammatory processes linked to the immune system and to maintain fertility in both sexes. Even more important, though, is the relationship between vitamin E and a little known mineral—selenium. It has been demonstrated that vitamin E and selenium "spare" each other.[21] This means that they protect each other's reserves. Therefore, a reduced level of vitamin E would affect selenium's status also.

Let's examine this relationship more closely. One of selenium's roles "in vivo" is that it is a vital part of that previously mentioned hormone glutathione peroxidase. Its function is to change one of the chain reaction initiators—hydrogen peroxide (H_2O_2)—into water (H_2O). Additionally, ascorbic acid returns vitamin E to its previously unoxidized state, thus allowing the same vitamin E to continue blocking the oxidation process.

You should take away from this article the general concept that anything that changes hydrogen peroxide into water is good stuff, indeed. See, biochemistry isn't so hard after all!

Conclusion: Rancidity is the end condition of fats and oils given the process of oxidation in the production of free radicals. Both natural vitamin C- and E-based antioxidants and synthetic antioxidants are available to dog food manufacturers. Rancid foods are unpalatable. Prevention of rancidity is not without risks. Shelf-life and storage requirements determine whether synthetic antioxidants are required. In ascending order of risk are BHA, BHT and ethoxyquin. There is no doubt that ethoxyquin is a more effective antioxidant than the other synthetic antioxidants available to dog food manufacturers.

References:

1. Dan Meyer, D.V.M., Federal Foods, Mequon, Wis., makers of Fromm dog food.

2. Arleigh Reynolds, D.V.M., Cornell University, *Mushing*, May 1993.

3. Larry Macklin, Ph.D., Hoffman-LaRoche, conversation, August 1993.

4. Fairburn, Grootveld, Ward, Abiuka, Kuf, Williams, Winyard and Blake, "Alpha-tocopherols, lipids, and lipoproteins in knee-joints, synovial fluid and serum from patients with inflammatory joint disease," *Clinical Science*, 1992; Vol. 83: pp. 657-664.

5. Lucy and Diplock, February Letters, February 1973; Vol. 29: pp. 205-210.

6. Lucy and Dingle, "Fat soluble vitamins and biological membranes," *Nature*, Oct. 10, 1964; Vol. 204: pp. 154-160.

7. Cheeke and Shull, "A vitamin E deficiency in rats not responsive to selenium or a synthetic antioxidant," *Oregon Agricultural Experiment Station Technical Paper Number 2*, August 1972; Vol. 6, No. 2.

8. Riis, Sheffy, Loew, Kern, Smith, "Vitamin E deficiency retinopathy in dogs," *American Journal of Vet Res*, January 1981; 42(1): pp. 74-86.

9. Ingold, Bowry, Stocker, Walling, "Autoxidation of lipids and antioxidation by alpha-tocopherols and uviquinol in homogenous solutions and in aequeous dispersions of lipids: unrecognized consequences of lipid particle size as exemplified by oxidation of human low density lipoprotein," *Proceedings of National Academy of Science USA*, January 1993; Vol. 90, pp. 45-49.

10. Malkinson, A.M., "Genetic studies on lung tumor susceptibility and histogenesis in mice," *Environmental Health Perspectives*, June 1991; Vol. 93, pp. 149-159.

11. Clayson, Iverson, Nera, Lok, "The importance of cellular proliferation induced by BHA and BHT," *Toxicology and Ind. Health*, August 15, 1993; 40(4): pp. 677-84.

12. Ferreira, "Effect of butylated hydroxyanisole on electron transport in rat liver mitochondria," *Biochemical Pharmacology*, August 15, 1990; 40(4): pp. 677-84.

13. *International Journal of Hypothermia*, May-June 1992; Vol. 8(3): pp. 351-362.

14. Van Ommen, Koster, Verhagen, Van Bladeren, "Gluthathione conjugates of tert-butyl hydroquinone as potent redox cycling agents and possible reactive agents underlying the toxicity of butylated hydroxyanisole," *Biochem Biophys Res Commun*, Nov. 30, 1992; 189(1): pp. 309-314.

15. Knight, Voorhees, Martin, "The effect of metal chelates on lipid peroxidation in stored erythrocytes," *American Clinical Lab Science*, July-August 1992; 22(4): pp. 207-213.

16. McLellan, Harrison, Hayes, "Modulation of glutathione s-transferases and glutathione peroxidase by the anticarcinogen butylated hydroxyanisole in murine extrahepatic organs," *Carcinogenesis*, Dec., 13, 1992; (12), pp. 2255-2261.

17. FDA Petition, Docket Number 93P0081/CP1 accepted February 25, 1993, submitted by Carol Barfield, President, United Animal Owners Association, 3851 W. 146th St., Cleveland, OH 44111.

18. Skaare, Janneche, "The effect of ethoxyquin on the intestinal transport of glucose and water in vitro," Letters to the Editor, *ACTA Pharmacol. et Toxicol*, 1976; Vol. 38, p. 174.

19. Nafstad and Skaare, "Ultrastructural hepatic changes in rats after oral administration of ethoxyquin," *Toxicology Letters*, 1, 1978, pp. 295-299.

20. Meydani M., Meydani S.N., Shapiro A.C., Macauley J.D., Blumberg, "Influence of dietary fats, vitamin E, ethoxyquin and indomethacin on the synthesis of prostaglandin E_2 in brain lesions of mice," *Journal of Nutrition*, April 1991; Vol. 121, pp. 438-444.

21. Christine, Cayhill, Lucy, Diplock, "The effect of vitamin E on the intracellular distribution of the different oxidation states of selenium in rat liver," *Biochem Journal*, 1971; Vol. 125, pp. 407-416.

Part V

Some synthetic antioxidants may lead to diet deficiencies that contribute to reproductive difficulties and immune system failure

Conclusions from "Feed that dog! Part IV" (October 1993 issue): Rancidity is the end condition of fats and oils given the natural process of oxidation in the production of free radicals. Driving the whole issue of preserving feeds is the length and condition of storage. Natural and synthetic antioxidants are available to dog food manufacturers; however, the synthetic, and more effective, antioxidants are not without major problems. At some level each becomes toxic. The question to be answered is whether the problems outweigh the benefits.

Breed magazines and club newsletters have been circulating various anecdotal stories concerning the impact of synthetic antioxidants on reproductive and immune systems and the increased incidence of cancer occurring in dogs.

Reproductive difficulties: Failure of bitches to come into heat, sterility in the male, low sperm count, lack of sperm motility, reabsorption of fetuses, malformed puppies, uterine inertia and failure to thrive are common anecdotal problems. What we want to do in this article is to dispel reliance on anecdotal evidence. The scientific literature is adequate to establish that there are reproductive problems resulting from use of synthetic antioxidants.

• *Decreased prostaglandin synthesis:* The most powerful of the synthetic antioxidants in widespread use is ethoxyquin. In 1991, a Tufts University study demonstrated that ethoxyquin reduced the blood plasma level of α-tocopherol by 42 percent and paradoxically decreased prostaglandin E_2 synthesis.[1] Vitamin E is a mixture of eight different compounds, the most "active" form of which is α-tocopherol. Sterility in the male and loss of sperm motility as well as fetal reabsorption can be caused by a vitamin E deficiency.[2]

• *Reduced vitamin E and PGE_2*: Normally, when the concentration of vitamin E is low, PGE_2 synthesis is high and vice versa (i.e., an inverse relationship). But ethoxyquin reduces both blood plasma levels of vitamin E and PGE_2 synthesis. The most important dietary PGE_2 precursor is the essential fatty acid, linoleic acid. For the purposes of this article, linoleic acid is converted to arachidonic acid by elongation and the enzymatic abstraction of hydrogen. Then, by a variety of different metabolic pathways, arachidonic acid is transformed into the various prostaglandins.

Linoleic acid→arachidonic acid→ prostaglandins

• *PGE_2*: A definite link exists between PGE_2 and modulation of ACTH (adrenocorticotrophic hormone). One of ACTH's functions is to simulate the cascade effect of cholesterol that eventually leads to the formation of esterone and testosterone (the female and male hormones). Prostaglandins also promote the contractions of smooth muscle which includes uterine muscle. There is anecdotal evidence relating ethoxyquin and uterine inertia.

Birth defects: Anecdotal evidence suggests a link between some of the gross birth defects experienced and ethoxyquin. For a possible explanation of these problems, we have to look at the relationship between vitamin E and the mineral selenium. Both vitamin E and selenium are free-radical scavengers and protect the body from their ill effects. Vitamin E operates within the cell membrane and selenium is the major component of the active site of the enzyme glutathione peroxidase.[3] From Part IV in this series, you will remember that glutathione peroxidase is the good stuff which converts hydrogen peroxide into water. Glutathione also functions as a cofactor in PGE_2 synthesis.

One of the stranger aspects of selenium, however, is that it exhibits the same effects if there is too little or too much within an organism. It is extremely toxic (see Feed II), also, and has been known to cause birth defects. The anomalies most often seen are bone closure defects, i.e., cleft palate.[4] In one post-mortem examination done on the kidneys of a litter known to the authors, the selenium levels varied from 0.95 ppm (parts per million) to 2.35 ppm even though the normal amount should run between 4.0 to 6.0 ppm.[5] So what is the relationship between vitamin E and selenium? The accepted role of vitamin E is that it maintains selenium in a "reduced" state.[6] Remember, a molecule or atom is reduced when it gains an electron (it becomes more negative, i.e., reduced). The oxidation number, also known as the oxidative state of selenium, can vary from (+6) to (-2), but it functions best in the body as a selenide (Se^{-2}). Vitamin E's job is to keep selenium in the (-2) oxidative state.[7]

Failure to thrive: Selenium has other functions within the body, possibly even more important than its role as an antioxidant. These functions are just now being examined and their mechanisms, or how they operate, explained.[8] What has been demonstrated though is the relationship between vitamin E, selenium and the immune response.[9]

As early as 1972, it was shown that vitamin E and selenium played a role in late-stage antibody formation.[10] A more recent study in 1985 determined that dietary deficiencies of vitamin E and selenium depressed natural killer cell-mediated cytotoxicity (NKCC) and T-lymphocyte-mediated cytotoxicity (TCMC).[11] There we go, throwing those big words at you once again, so let us explain. What all three types of immune response have in common is that they are all *cell membrane controlled functions.*

Natural killer (NK) cells and T-lymphocytes function by attacking intruders, also known as antigens (*anti*body

*gen*erating) that have already invaded a cell, but have not yet begun to reproduce. As an example, take a cell that has been invaded by a virus: Viruses are non-facultive. This means that they are unable to reproduce themselves. In fact, viruses are inanimate, i.e., they are nothing more than DNA or RNA genetic coding material with a protein coating.

Viruses are ingested by other cells which are then "infected." The next step in the process of infection is the insertion of the viruses' own DNA or RNA in place of the host cells.

Thus, the virus is replicated by the very cells that ingest them. Obviously, it would be in the best interest of the host to be able to kill such infected cells before they have a chance to reproduce themselves. NK cells appear to do just that.

How they recognize an infected cell is just now being explained. It seems that once infected, the cells display particular large molecular weight glycoproteins (sugar proteins) embedded in their cell membranes, which NK cells recognize. This recognition occurs through receptors on the NK cell surface, which brings the two cells close together. This positioning "activates" the NK cells and they release granules that contain a chemical that forms pores in the membrane of the infected cell, thus causing it to die.

T-lymphocyte-mediated toxicity functions in a little bit more complex manner. T-cells only recognize antigen when it is on the surface of a body cell. Accordingly, its surface receptors recognize antigen plus a surface marker which tells the T-lymphocyte that it is making contact with another cell. These cell markers belong to an important group of molecules known as the major histocompatabilty complex (MHC).

The message you should take home from this is that both types of immune cells attack cells that are already infected or parasitized and their cellular functions depend upon "cell membrane" recognition sites. With decreased levels of vitamin E and selenium, free-radical damage might impair the "cell killing" apparatus and damage to the cell membranes could alter target cell recognition and subsequent binding capabilities.

The same system is probably operating on late-stage antibody formation. Antibodies bind to antigens and either inactivate them or start a process that eventually leads to their destruction. Before the production of antibody can start though, the antigen that initiates the original immune response must first be "presented" to the B-lymphocytes, and this is a function of the cell membrane also. Thus it is possible that perturbations of the cell membrane due to lipid peroxidation could hamper this phase of the immune response.

In a more recent study, some researchers in Wales discovered that vitamin E and selenium dietary deficiencies actually affected the determination of immuno-competent cells.[12] In other words, cells that lacked sufficient vitamin E and selenium were not "deciding" to become B- or T-lymphocytes.

When just "born," cells divide a certain number of times before differentiating into a specific type of tissue. Once "determined" onto a certain cellular pathway, most cells cannot go back to the "undetermined" stage. The end result of these dietary deficiencies is a reduced number of cells dedicated to the body's immune system and that would definitely not be a good scenario.

By now, you should be asking yourself the following question: If these previously mentioned consequences are solely the result of free-radical damage, then why don't the synthetic antioxidants protect us and our animals?

The obvious answer is that there must be another mechanism operating here. Vitamin E is really not all that efficient as an antioxidant.[13] Because it has a long "fatty" tail (the synthetic antioxidants do not have such a tail), it takes a lot of energy for it to be in the aqueous or watery parts of the cell. Nature likes to conserve energy, so as a consequence vitamin E resides quite happily within the various cellular membranes. This limits the types of free radicals it can interact with and the frequency of those interactions. However, vitamin C operates within the aqueous portion of the cell, and the two vitamins complement each other and cover all types of free radicals.

Vitamin E physically stabilizes the cell membrane by filling in the spacing of the lipid bilayer. Those antioxidants with shorter tails or no tails at all actually disrupt the ordering of the membrane lipids.[14,15] Such defects can lead to membrane damage.[16] In fact, a very recent article on inhibition of cell proliferation by vitamin E shows an inverse relationship between tail length and cellular toxicity.[17] The shorter the tail, the more toxic the molecule is to the cell.[18]

Conclusions: Anecdotal evidence of antioxidant disruption of reproductive and immune systems is good as far as it goes, but until scientific inquiry supports the same contentions, anecdotal evidence must always be considered suspect. What we have presented in this article are plausible explanations of problems associated with reproduction and immune systems. In Part IV of this series, we presented that ethoxyquin was the most powerful of the antioxidants in common use as a preservative. We have addressed concerns with ethoxyquin under the assumption that its use should be curtailed until adequate testing has been done to determine its safety.

References:

1. Meydani M., Meydani S.N., Shapiro A.C., Macauley J.D., Blumberg, "Influence of dietary fats, vitamin E, ethoxyquin and indomethacin on the synthesis of prostaglandin E_2 in brain lesions of mice," *Journal of Nutrition*, April 1991; Vol. 121, pp. 438-444.

2. Tomassi G., Silano V., "An assessment of the safety of tocopherols as food additives," *Fd. Chem. Toxic.*, 1986; Vol. 24, No. 10/11: pp. 1051-1061.

3. Spalholtz J.E., Martin J.L., Gerlach M.L., and Heinzerling R., "Immunologic response of mice fed diets supplemented with selenite sodium," *Proc. Soc. Exp. Biol. Med.*, 1973; 143, p. 685.

4. Bee Search, *Sacramento Bee*. Conversation August 25, 1993; from a series on selenium toxicity in waterfowl of the Sacramento Valley wetlands.

5. Chemistry toxicology report, Diagnostic Lab, Colorado State University, Fort Collins, Colo. 80523 February 12, 1992.

6. Spalholtz J., Personal conversation, August 27, 1993.

7. Ibid.

8. Burke, Read, Hill, Bellew, "Response of rat selenoprotein P to selected administration and fate," *American Journal of Physiology*, 1991; Vol. 261, pp. E26-E30.

9. Turner R.I., Finch J.M., "Selenium and the immune response," *Proc. Nutr. Soc.*, 1991; 50, pp. 275-285.

10. Burke, et al.

11. Meeker H.C., Eskew M., Scheuchenzubber W., Scholze R.W., and Zarkower A., "Antioxidant effects on cell-mediated immunity," *Vet Med*, Penn State University Press, pp. 451-458.

12. Turner et al., "Selenium."

13. Kagan V.E., Serbinova E.A., Bakalova R.A., Storychev T.S., Erin A.N., Prilipko L.L., and Eustigneeva, "Mechanisms of stabilization of biomembranes by alpha-tocopherol—the role of the hydrocarbon chain in the inhibition of lipid peroxidation," *Biochem. Pharm.,* 1990; Vol. 40, No. 11: pp. 2403-2413.

14. Ibid.

15. Kagan V.E., Serbinova E.A., Novikov K.N., Ritov, V.B., Kozlov L., Stoichev T., "Toxic and protective effects of antioxidants in biomembranes," *Arch. Toxicol. Suppl.,* 1986, pp. 302-305.

16. Ibid.

17. Kagan V.E., Serbinova E.A., Forte T., Scita G., Packer L., "Recycling of vitamin E in human low density lipoproteins," *J. Lipid Res.*, 1992; 33: pp. 385-397.

18. Chatelain E., Boscoboinik D., Bartoli G., Kagan V., Gey F., Packer L. and Azzi A., "Inhibition of smooth muscle cell proliferation and protein kinase C activity by tocopherols and tocotrienols," *Biochemica et Biophysica Acta,* 1176, 1993, pp. 83-89.

Part VI

Evidence suggests that common substances may interact with some antioxidants in ways that increase their carcinogenic effects

Conclusions from "Feed that dog! Part V" (November 1993 issue): Anecdotal evidence of antioxidant disruption of reproductive and immune systems is good as far as it goes, but until scientific inquiry supports the same contentions, anecdotal evidence must always be considered suspect. What we have presented in this article are plausible explanations of problems associated with reproduction and immune systems. In Part IV of this series, we presented that ethoxyquin was the most powerful of the antioxidants in common use as a preservative. We have addressed concerns with ethoxyquin under the assumption that if it can be determined to be safe, it is probable that BHA and BHT are safe at some level.

This is a particularly important article. While there is a general belief that cancer is on the increase, it is not clear why. One camp argues pesticides, preservatives, industrial chemicals, smoking, etc.; another argues genetic selection; another argues longevity. There is a problem with writing about things that cause cancer. For instance: In the '50s it was a foolish thing to write about the link between cigarettes and cancer. Those who did got squashed like fleas. Today, however, more and more carcinogens in common use are being identified.

With the above in mind, we will attempt to discuss cancer from a non-emotional point of view, and to distill a great amount of scientific literature into paragraph-sized chunks. In order to make life simpler for those who wish to examine references, we draw heavily in the first part of the article from the Robbins text, which is familiar to several decades of medical students, and therefore readily available.

We ask that you integrate the material covered into a single understanding that there are problems with synthetic antioxidants in general and that establishing safe levels is extremely important, as is determining what synergy or multiplicative or cumulative effects there may be when used with other products. For example, evidence suggests that common substances may interact with common antioxidants in ways that increase their toxic or carcinogenic effects.

Before we can adequately talk about the relationship between cancer and the use of antioxidants, we must first discuss briefly what cancer is, and define some of the terms and processes associated with this illness.

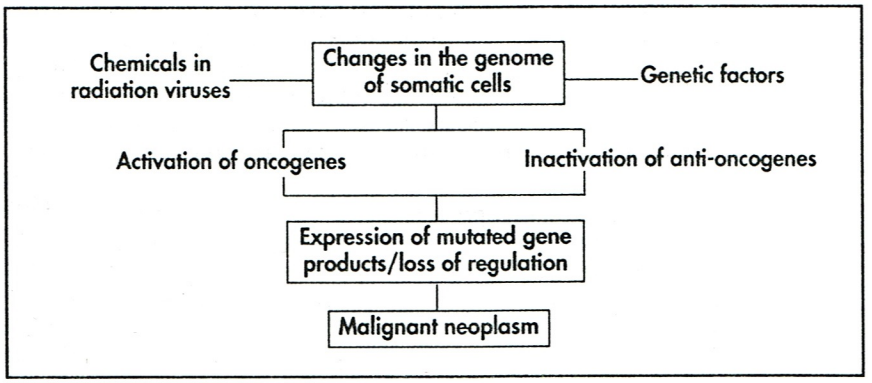
As a disease process, cancer is not just one disease, but more than 100 diseases. The various forms of cancer are classified according to the type of tissue from which they arise. For example, if they arise from bones or connective tissue, they are known as sarcomas; those that stem from cells that line the internal or external body surfaces are called carcinomas; and those from blood or lymph systems are referred to as leukemias and lymphomas. Table 1 shows the classification of tumors based on their tissue of origin. Figure 1 shows the basic pathogenesis of cancer. What all these types of cancer have in common is that they are characterized by abnormal cell growth, or neoplasia, which is the result of a malfunction in the body's growth-regulating mechanisms.

So what causes cancer? What is it that not only alters normal cells in such a way that they can no longer be controlled by the body's own regulatory and developmental processes, but also allows these aberrant cells to hide from the body's own natural control mechanisms? Researchers believe that there are two components to the initiation of cancer—a viral relationship and a genetic aspect.

Before we can discuss this, however, we need to define two terms: initiation (also called induction) and promotion.

Initiators are those substances that damage either the whole cell or its nucleus (where the genetic material is stored). An initiated cell is a cell that has been exposed to an appropriate dose of a carcinogenic agent (initiator), and as a result has been altered in a manner that makes it likely to give rise to a tumor (neoplasm). Such initiation is both rapid and irreversible. It is believed that initiating carcinogens produce permanent changes

Figure 1


Chemicals in radiation viruses
Changes in the genome of somatic cells
Genetic factors
Activation of oncogenes
Inactivation of anti-oncogenes
Expression of mutated gene products/loss of regulation
Malignant neoplasm

in the DNA of target cells.[1]

Promoters are unable to induce cancer themselves. That is, they are non-tumorigenic in that they cannot induce cancer except in previously initiated cells. They do, however, have the ability to speed up and maintain the cancerous process. Cellular changes resulting from promoters are reversible.[2] Promoters appear not to damage DNA.[3]

Cancer development is a two-stage process. First, the cell is damaged beyond its ability to repair itself, and second, it is exposed to a substance that promotes rapid growth or replication. So we ask again: What causes cancer? Let us first look at the genetic aspect. It is thought that all living organisms have a small number of genes in their cells that have the ability to transform normal cells into cancerous ones. These genes are called oncogenes and they arise from normal genes that are present in healthy cells. In their normal form, these genes are called proto-oncogenes, and it should not come as a surprise to anyone that their function is to control cell growth and development.

Cancer arises when a genetic mutation occurs that changes a proto-oncogene into an oncogene. Oncogenes act to promote abnormal growth and they function even when the cell has a mutation in a single copy of the gene. The other copy may be normal, but the oncogene mutation is dominant and promotes cancer. Chemicals that initiate carcinogenesis are extremely diverse in structure and may be synthetic or natural products. Initiating agents by definition are carcinogens.[4] There are two basic initiator categories:

Tissue of Origin	Benign	Malignant
I. Composed of one parenchymal cell type		
A. Tumors of Mesenchymal origin		**Sarcomas**
1. Connective tissue and derivatives	Fibroma Myxoma Lipoma Chondroma Osteoma	Fibrosarcoma Myxosarcoma Liposarcoma Chondrosarcoma Osteogenic sarcoma
2. Endothelial and related tissues *Blood vessels* *Lymph vessels* *Synovia* *Mesothelium* *Brain coverings* *Glomus*	 Hemangioma Lymphangioma Meningioma Glomus tumor	 Angiosarcoma Lymphangiosarcoma Synoviosarcoma Mesothelioma Invasive meningioma
3. Blood cells and related cells *Hematopoietic cells* *Lymphoid tissue*		 Myelogenous leukemia Monocytic leukemia Malignant lymphomas Lymhocytic leukemia Plasmacytoma Histiocytosis X
4. Muscle *Smooth muscle* *Striated muscle*	 Leiomyoma Rhabdomyoma	 Leiomyosarcoma Rhabdomyosarcoma
B. Tumors of epithelial origin		**Carcinomas**
1. Stratified squamas	Squamous cell papillomas	Squamous cell carcinoma
2. Basal cells of skin or adnexa		Basal cell carcinoma
3. Skin adnexal glands *Sweat glands* *Sebaceous glands*	 Sweat gland adenoma Sebaceous gland adenoma	 Sweat gland carcinoma Sebaceous gland carcinoma
4. Epithelial lining *Glands or ducts* *well-differentiated group* *poorly-differentiated group*	 Adenoma Papilloma Papillary adenoma Cystadenoma	 Adenocarcinoma Papillary carcinoma Papillary adenocarcinoma Cystadenocarcinoma Medullary carcinoma Undifferentiated carcinoma
5. Respiratory passages		Bronchogenic carcinoma Bronchial "adenoma"
6. Neuroectoderm	Nevus	Melanoma
7. Renal epithelium	Renal tubular adenoma	Renal cell carcinoma
8. Liver cells	Liver cell adenoma	Hepatoma
9. Bile duct	Bile duct adenoma	Bile duct carcinoma
10. Urinary tract epithelium	Transitional cell papilloma	Papillary carcinoma Transitional cell carcinoma Squamas cell carcinoma
11. Placental epithelium	Hydatidiform mole	Choriocarcinoma
12. Testicular epithelium		Seminoma Embryonal carcinoma
II. More than one neoplastic type--mixed tumors--usually derived from one germ layer		
1. Salivary glands	Pleomorphic adenoma	Malignant mixed tumor of salivary gland origin
2. Renal analge		Wilm's tumor
III. More than one neoplastic cell type derived from more than one germ layer		
1. Totipotential cells in gonads or in embryonic tissue	Mature teratoma, dermoid cysts	Immature teratoma

Table 1. Nomenclature of Tumors (adapted from "Robbins Pathological Basis of Disease, 4th Ed.")

- Direct-acting compounds, carcinogens, do not require any chemical transformation to be carcinogenic.
- Indirect-acting compounds, procarcinogens, require some form of metabolic conversion in vivo (in the body) in order to produce a metabolite capable of transforming cells. Except for the few direct-acting compounds, most chemical carcinogens require metabolic conversion into ultimate carcinogens with DNA as their primary target.[5]

Another genetic component to the cancer process are the tumor-suppressor genes. These genes' normal function is to prevent cell growth. They are recessive in their expression in that only one normal copy is sufficient to keep cell function normal. However, if both copies of the gene are lost or damaged, cancer develops. Alternatively, some cancers occur not by activation of oncogenes, but through inactivation of anti-oncogenes whose function is to suppress abnormal cell proliferation.[6] While this is a subtle difference, it is of major importance because of the ability to depress the immune system with synthetic antioxidants.

We should now look at the viral relationship in the initiation of cancer. It is, in effect, just another aspect of the genetic component. Remember, a virus is simply a segment of either DNA or RNA, covered with a protein coat. In order to duplicate itself, it must take over the host cell's replication system. It has been suggested that perhaps half a billion years or so ago, certain viruses accidentally incorporated into their own genes copies of those of certain animals that they had infected.

The "hitchhiking" genes sometimes included ones that caused cancer, but without cofactors such as environmental toxins, radiation or genetic changes, they stay dormant. Cancer is induced or initiated when these pre-

cancerous genes are activated, and there are at least three different ways this can occur.

• First is a point mutation, which is a tiny change in one of the molecules that make up DNA.

• Second, cancer genes can be activated by normal genes being moved from one chromosome to another. These accidental movements are called chromosomal translocations and are believed to occur during the early stages of development when there is rapid growth. Some researchers believe that this translocation of genes pulls a proto-oncogene away from neighbors that control it.

• Third is when activation occurs. It involves a dramatic increase in the synthesis of that portion of the genome (an organism's complete genetic material) that contains the oncogene, with a corresponding increase in the production of the proteins that these genes control. We now have enough background to start looking at the relationship between cancer and antioxidants.

Remember from previous articles in this series that antioxidants react with free radicals and terminate the chain reaction that leads to multiple free-radical molecules. But free radicals can have a beneficial function also. One of these functions is within the immune system, where the body uses free radicals to destroy cells that the immune system perceives as harmful. Once the free radical is used for this purpose, the body also has a method of containment that protects the living organism from its harmful effects. One of these deleterious effects is damage to the molecules that make up DNA—in effect, they are mutagens.

Cancer researchers have focused on this quality, and are thinking that if free radicals can induce cancer by mutating DNA, couldn't antioxidants prevent the initiation of cancer? For the last several years, the results of these researches have been published and those results are disturbing and contradictory, at least those involving synthetic antioxidants.

In one study, the simultaneous administration of a known mutagen and the antioxidant ethoxyquin significantly reduced the clastogenic (breaking apart of DNA/RNA) effects of the mutagen.[7]

On the other hand, a study in 1984 demonstrated that the four most commonly used synthetic antioxidants—BHA, BHT, ethoxyquin and propyl gallate—actually increased the toxicity of other chemicals, increased mutagen activity, increased the sensitivity of an organism exposed to radioactivity and increased the tumor yield from chemical carcinogens.[8]

A more recent study looked at phenolic compounds in general (which includes the natural and synthetic antioxidants) and it was found that they induce double-strand DNA breaks, DNA adducts, mutations and chromosomal aberrations in a great variety of test systems.[9]

As for the protection against free radical damage to DNA, several studies show that the synthetic antioxidants actually increase the hydrogen peroxide formation in rat liver and lung microsomes and that extra H_2O_2 production was maximized between 50 and 500 ppm.[10] (Ethoxyquin is approved by the Food and Drug Administration for use at 150 ppm in dog foods.)

As a further example we would like to quote from a Dutch study published in 1991.[11] "It is hypothesized that BHA gives rise to tumor formation in rodent forestomachs by inducing heritable changes in DNA. Evidence is being provided that reactive oxygen species, in particular hydroxy-radicals, may play a crucial role."

BHA is specifically mentioned as a bladder tumor promoter in a recent Japanese study.[12]

BHA enhanced forestomach carcinogenesis but did not enhance esophageal carcinogenesis. BHT enhanced esophageal carcinogenesis but did not promote forestomach carcinogenesis. Ethoxyquin significantly enhanced esophageal tumorigenesis.[13]

In another Japanese study, it was demonstrated that the synthetic antioxidants BHA, BHT and ethoxyquin either promoted or inhibited carcinogenesis, depending on the organ involved and the chemical used as an initiator.[14]

"BHA clearly induced squamous cell carcinomas . . ."[15]

". . . induction of hyperplasia [excessive growth] was not inhibited, but increased by the antioxidants, particularly propyl gallate and ethoxyquin."[16]

"We conclude that the important food preservatives BHT and BHA accelerate the kinetics of terminal differentiation of human leukemia and that this effect is likely due at least in part to their membrane-active properties."[17]

"These results indicate that BHA should be classified in the category of sufficient evidence of carcinogenicity, as judged by the IARC [International Association of Registered Carcinogens] criterion."[18]

With just these few citations mentioned, it seems obvious that we need to look again at the use of synthetic antioxidants, as opposed to natural ones. It must be noted, however, that there are approximately 30 known chemical carcinogens of natural origin. The primary natural carcinogen of concern to dog owners is the potent hepatic carcinogen aflotoxin B1. Aflotoxin B1 is a toxic metabolite of some strains of *Aspergillus flavus* that live and prosper on improperly stored grains. Aflotoxin B1 is further metabolized by hepatic oxygenases to yield a dihydrodiol epoxide—the "ultimate carcinogen."[19] Dog foods are cereal foods, regardless of the advertising "chicken-, lamb-, meat-based" claims as was documented in earlier articles in this series.

We can summarize chemical carcinogenesis as follows:[20]

• Most chemical carcinogens are mutagenic.

• Mutagens bind to DNA, causing miscoding errors in transcription and/or replication.

• Chemical carcinogens are important because they operate on critical genes, which are dominantly acting oncogenes or recessive cancer suppressor genes.

• Carcinogenicity of various agents is dose-dependent. Note that fractional doses over time can have the same impact as a single comparable dose. Once achieved, the critical carcinogenic dose (initiating dose) is virtually irreversible. This is what makes the establishment of safe and toxic levels so very important for antioxidants used in the preservation of dog foods.

Given this dose-dependent nature of carcinogens, it is critical that appropriate evaluation of antioxidants, acting by themselves and in concert with other chemicals, such as pesticides and vaccines, be made before they are introduced to the marketplace in dog foods (or human foods). Unfortunately, this is not routinely done. Chemicals are evaluated on their own merit, without concern for their combined properties with other commonly available chemicals. In the case of ethoxyquin, the FDA has a checkered history:

FDA Talk Paper T89-71, November 2, 1989, states that the Monsanto five-year study was sufficient.

FDA letter, August 11, 1993, in response to Petition, Docket No.93P-0081/CP 1, states, "The study (Monsanto five-year) was found deficient in establishing either the

safety of ethoxyquin or lack thereof."

The FDA now finds itself in a position of not being able to rationally justify its approval of ethoxyquin. Specifically, the one-year Hazelton Labs study was the only one used in the approval process. Just to give you an understanding that "something is rotten," here are just a few of the flaws in the Hazelton study:

Only three dogs per test group were used. This is not exactly a statistically meaningful sample size. Remember from your statistics classes the "Law of Large Numbers" and the attempt to have n > 30? While not a fatal flaw, the confidence interval is so large that virtually no meaningful statistical inference can be drawn.

Ethoxyquin was provided via capsule. Ethoxyquin is a feed preservative. Chemical interaction with feed was not determinable.

Dogs received ethoxyquin five days per week—104 days were unaccounted for in the study. This is a fatal flaw.

One out of three dogs receiving 3 mg/kg/day (the FDA safe level) had adverse reactions, yet this is the established "safe" level.

FDA review, March 22, 1981, of the one-year study: "The short administration time of level 2 and early sacrifice makes the interpretation of toxicological data questionable. . . ."

One more tidbit to whet your appetite: "Ethoxyquin is your best antioxidant for feedstuffs because: It improves carcass stability."[21] Here is your opportunity to stabilize the carcass of your favorite dog while it is still on its feet!

For more information on this subject, contact the United Animal Owners of America.[22]

Conclusions:

Beyond a shadow of a doubt, at some level of ingestion, synthetic antioxidants are inducers or promoters of neoplasia, i.e., cancer. True safety and toxic levels are not well known or adequately researched in the dog. The FDA tells us that we cannot extrapolate from one species to another with any degree of certainty. There is no sufficient species-specific study in dogs, yet there is FDA approval of ethoxyquin at rates well above the levels which demonstrably produce adverse reactions.

We all get to choose what we buy. During the writing of this series on canine nutrition, the authors talked to a large number of dog food manufacturers and researchers. The consensus generally has been that they like the idea of using a long-acting preservative and that they are more aware of the problems with BHA and BHT than they are with ethoxyquin. Many feel the problem will be overcome by events in two years. Because the consumer has become informed, they will no longer be able to market a product laced with carcinogens. Research continues into vitamin E-based preservatives—there is hope that we may be able to move away from absolute reliance on carcinogenic synthetics. Be aware, however, that *Aspergillus flavus* is still out there awaiting the opportunity to create toxic metabolites (Aflotoxin B1) in unprotected grains.

References:

1. Cotran, R.S.; Kumar, V.; and Robbins, S.L., Saunders, W.B., "Robbins Pathologic Basis of Disease, 4th Ed.," Philadelphia, 1989, p. 268.

2. Ibid., p. 269.

3. Ibid.

4. Ibid., p. 270.

5. Ibid., p. 273.

6. Ibid., p. 289.

7. Renner, H.W. and Knoll, M., "Antimutagenic effects on male germ cells of mice," *Mutat Res,* June-July 1984; 140(2-3): pp. 127-9.

8. Kahl, R., "Synthetic antioxidants: biochemical actions and interference with radiation, toxic compounds, chemical mutagens and chemical carcinogens," *Toxicology*, December 1984; 33(3-4): pp. 185-228.

9. Stich, H.F., "The beneficial and hazardous effects of simple phenelic compounds." *Mutat Res,* March-April 1991; 259(3-4): pp. 307-24.

10. Kahl, R. and Hildebrand, A.G., "Effect of synthetic antioxidants on hydrogen peroxide formation, oxyferro cytochrom P-450 concentration and oxygen consumption in liver microsomes," *JPN J Cancer Res,* July 1992; 83(7): pp. 699-704.

11. Vehegan, H., Schilderman, P.A., and Kleinjans, J.C., "Butalyted hydroxyanisole in perspective," *Chem Biol Interact,* 1991; 80(2): pp. 109-34.

12. Shibata, M.A., Fukushima, S., Asakawa, E., Hirose, M., and Ito, N., "The modifying effects of indomethacin or ascorbic acid on cell proliferation induced by different types of bladder tumor promoters in rat urinary bladders and forestomach mucosal epithelium," *JPN J Cancer Res,* January 1992; 83(1): pp. 31-9.

13. Fukushima, S., Sakata, T., Tagawa, Y., Shibata, M.A., Hirose, M., and Ito, N., "Different modifying response of butylated hydroxyanisole, butylated hydroxytoluene, and other antioxidants in N, N-dibutylnitrosamine esophagus and forestomach carcinogenesis of rats," *Cancer Res,* April 15, 1987; 47(8): pp. 2113-6.

14. Ito, N., Hirose, M., Fukushima, S., Tsuda, H., Shirai, T., and Tatematsu, M., "Studies on antioxidants: their carcinogenic and modifying effects on chemical carcinogenesis," *Food Chem Toxicol,* October-November 1986; 24(10-11): pp. 1071-82.

15. Ito, N., Hirose, M., Fukushima, S., Tsuda, H., Tatematsu, M.; and Asamoto, M., "Modifying effects of antioxidants on chemical carcinogenesis," *Toxicol Pathol,* 1986; 14(3): pp. 315-23.

16. Hirose, M., Hagiwara, A., Masui, T., Inoue, K., and Ito, N., "Combined effects of butylated hydroxyanisole and other antioxidants in induction of forestomach lesions in rats," *Cancer Lett,* February 1986; 230(2): pp. 169-74.

17. *J Cell Physiol,* July 1990;144(1): pp. 36-41.

18. Ito, N., Fukushima, S., and Tsuda, H., "Carcinogenicity and modification of the carcinogenic response by BHA, BHT and other antioxidants," *Critical Rev Toxicol,* 1985; 15(2): pp. 109-50.

19. Robbins, p. 272.

20. Ibid., p. 273.

21. Protecting Feeds and Feed Ingredients with Santoquin Ethoxyquin Antioxidant. Monsanto.

22. United Animal Owners Association, 3851 W. 146th St., Cleveland, Ohio 44111, Carol L. Barfield, governor/central region; (216) 671-6988.

Part VII

Feeding homemade food or supplementing store-bought kibble allows better control of what your dog eats and may help identify allergies

Conclusions from "Feed that dog! Parts V and VI" (November and December 1993 issues): Anecdotal evidence of antioxidant disruption of reproductive and immune systems is good as far as it goes, but until scientific inquiry supports the same contentions, anecdotal evidence must always be considered suspect. Presented are plausible explanations of problems associated with reproduction and immune systems. Ethoxyquin is the most powerful of the antioxidants in common use as a preservative. Synthetic antioxidants are inducers and promoters of neoplasia. True "safe" and "toxic" levels are not well known or researched in the dog. There is no sufficient species-specific study in dogs, yet there is Food and Drug Administration approval of ethoxyquin at rates well above the levels which produce demonstrable adverse reactions.

In this article we will explore an alternative practiced by many dog fanciers, and in fact by most dog owners throughout the world, especially in the poorer countries of the Third World, where dogs are fed what is left over. If one is a purist, one does not cook for one's dog to save time or money; in fact, it quickly becomes a real chore if you have more than one dog or if you have one of the giant breeds. So why would or should dog owners put themselves through the extra effort and expense of preparing their dogs' food "from scratch"?

After having read the previous six articles in this series, you probably have a good idea why: Ingredients allowed in some dog foods, such as dehydrated feces, hydrolyzed feathers and pulverized peanut hulls, etc., preserved with synthetic antioxidants do not exactly inspire confidence! Inadequate and/or unbalanced vitamins and mineral ratios, and the use of dyes and preservatives to allow longer shelf life, are just a few additional reasons to be used in the argument that you should prepare your own pet food.[1]

Dr. Al Plecknor, a veterinary practitioner in the Los Angeles area, gives another reason why you should cook for your pet: the increased incidence of pet allergies. In his clinical practice, Plecknor has seen an alarming increase in allergic reactions in his patients. It has been reported numerous times in many publications that the largest source of revenue in small-animal veterinary practices is the treatment of skin conditions resulting from allergies. It is beyond the scope of this article to document the increase in pet allergies over time resulting from genetic selection for breeding and introduction of antigens in pet food. The general understanding, however, from talking with a number of small-animal practice veterinarians, is that allergies are on the increase.

Another name for allergy is hypersensitivity, which is an altered reaction to a foreign substance (antigen, or *anti*body *gen*erating), so that subsequent exposures to that same substance results in a pathological reaction. This reaction can range from a slight swelling and redness to a case of full-blown anaphylactic shock—from slight discomfort to an immediately life-threatening condition.

In his book "Pet Allergies: Remedies for an Epidemic," Plecknor explains his theory.[2] The basis for an allergic reaction is the genetically induced and/or the environmentally acquired deficiencies in the various hormones produced by the adrenal and thyroid glands. These reduced hormonal levels then lead to a loss of control over the immune regulatory system with the result that antigens are either over-processed or under-processed. The resultant stress on the dog's immune system caused by a combination of fluctuating hormonal levels and environmental "shocks," together with a genetic susceptibility, can lead to the loss of recognition of self: autoimmune disease.

To determine if your pet has a food allergy, Plecknor suggests you try the "Heidi Diet" for seven to 10 days. If your pet's symptoms are alleviated, then there is a good possibility it does have a food allergy. The diet described is not for long-term use, but is only used for diagnostic purposes.

Aside from the time and effort that has to be devoted to cooking the food, the owner must have a keen awareness of the dog's nutritional needs. It is very important that your dog receive the proper ratio of minerals and vitamins for its biologic stage (see Part II of this series).

Meat, for example, contains quite a bit of phosphorus, and if you feed a high-quality protein diet, it is necessary to balance the high phosphorus content with calcium.[3] Use an easily absorbed form of calcium, such as calcium lactate, calcium gluconate or chelated calcium. An alternative to calcium pills or powders is one-

Table 1—Mineral Synergisms

Element	Synergist Minerals
Ca	Mg-P-Cu-Na-K-Se
Mg	Ca-K-Zn-P-Cr
Na	K-Se-Co-Ca-Fe-Cu-P
K	Na-Mg-Mn-Zn-P-Fe
Cu	Fe-Co-Ca-Na-Se
Zn	K-Mg-Cr-P
P	Ca-Mg-Na-K-Zn-Fe
Fe	Cu-Mn-K-Na-Cr-P-Se
Cr	Mg-Zn-K
Mn	K-Zn-Mg-Fe-P
Se	Na-K-Cu-Mn-Fe-Ca

Table 2—Vitamin Synergists

Vitamin	Synergistic Vitamins
A	B2-C-E-B1-B6
D	B12-E
E	A-B6-C-B12-B1-B3-B10-D
B1	E-C-B6-B12-B3-B5-A-B10-B2
B2	A-B3-B10
B6	E-A-B1-B3-B5-B12-B10
B12	B1-B3-B6-E-B5-C-B10-D
C	A-E-B6-B3-B5
B3	B1-B2-B6-A-B5-E-B10
B5	C-E-A-B1-B3-B6-B10

Table 3—Vitamin-Mineral Synergists

Vitamin	Mineral Synergists
A	Zn-K-P-Mg-Mn-Se
D	Ca-Mg-Na-Cu-Se
E	Na-K-Ca-Fe-Mn-Zn-P-Se
B1	Se-Co-Na-K-Fe-Mn-Mg-Cu-Zn-P
B2	Fe-P-Mg-Zn-K-Cr
B6	Zn-Cr-Mg-Na-K-P-Fe-Mn-Se
B12	Se-Cu-Ca-Co-Na
C	Fe-Cu-Ca-Co-Na
B3	Zn-K-Fe-P-Mg-Mn-Na-Cr-Se
B5	Cr-Na-K-Zn-P

Ca = calcium; Mg = magnesium; Na = sodium; K = potassium; Cu = copper; Zn = zinc; P = phosphorus; Fe = iron; Cr = chromium; Mn = manganese; Se = selenium; Co = cobalt.

third teaspoon of eggshell powder (see "Weight-Loss Diet" recipe). All are available at health food stores.

Heidi Diet

2 cups *cooked* soybeans*
2 cups brown rice
1 minced celery
1 minced carrot
500 to 600 milligrams calcium

(* Some dogs cannot handle soybeans, as canines do not have the enzymes necessary to fully break down the carbohydrate portion of soybeans. If your dog does not handle this diet well, substitute cottage cheese and white potatoes.)

On the other hand, too high of an intake of calcium depresses intestinal zinc absorption, while an excess of zinc depresses copper absorption.[4] This impairment of uptake is known as mineral antagonism, and can occur at two levels, absorptive and metabolic. Absorptive antagonism occurs when one element prevents or impairs the uptake of another. Metabolic antagonism is a little more complicated. Many minerals and vitamins are cofactors in various metabolic processes.[5] Without the proper co-factors, metabolic pathways are blocked. Pathways susceptible to being block are the breakdown of proteins, carbohydrates and fats, or the synthesis of hormones and fatty acids.

A third relationship also exists where the insufficient intake of a mineral can allow toxic accumulation of another element. Toxic amounts of cadmium can build up in the presence of marginal or deficient zinc. Insufficient calcium or iron can result in the accumulation of toxic amounts of lead.

Alternatively, a fourth relationship exists when the excessive ingestion of an element can produce a deficiency in synergistic minerals. A good example of the relationship between minerals is the well-known connection between calcium, magnesium and phosphorus in their role in building and maintaining bone tissue. If this sounds confusing, it is; we suggest you re-read Part II of this series. As shown in Tables 1 through 3, there are important mineral, vitamin and mineral-vitamin synergisms. Ad hoc, willy-nilly or arbitrary combination of vitamins and minerals can lead to fatal toxic conditions. Be guided by the National Research Council's vitamin and mineral requirements.

To complicate matters, there are vitamin antagonisms, which usually operate on the absorptive level.[6] For example, uptake of vitamin E and vitamin A occurs through the same mechanism. An excess of one diminishes the uptake of the other and vice-versa. Vitamins A and D are mutually antagonistic. The excessive intake of vitamin D can increase the need for vitamin A, as it ameliorates vitamin D's toxic effects.

Vitamins are required as cofactors in many metabolic processes. Again, to complicate the process, frequently more than one kind of vitamin is required. So vitamins can have a synergistic relationship similar to minerals. Table 2 shows some of the vitamin synergistic relationships.[7]

To really complicate matters, minerals and vitamins can also act in concert. For example, vitamin E and selenium "spare" each other. Table 3 is a list of vitamin-mineral synergists.[8]

Formulation of the "ideal" canine diet is obviously quite complicated, and in this series of articles, we have just scratched the surface. Most people aren't prepared to embark on an in-depth study of nutrition in order to cook for their pets, so we have included a sampling of various diets and a chart for determining the caloric needs of your dog. The chart was developed as a result of telephone calls and letters with questions about the tables and charts in Part I of this series. It appears that weight in pounds is preferred over weight in kilograms and that cup measurements are preferred over weight measurements, and tables are preferred to graphs and/or equations.

Caloric Needs for Given Biological Stage*

Weight in Pounds	x 1.0 Adult Maintenance NRC–74	x 3.0 Just Weaned NRC–74	x 2.7 Early Growth NRC–74	x 1.7 Half Grown Late Pregnancy NRC–74	x 4.2 Lactating Bitch NRC–74
1	73	221			
2	123	372	329		
4	207	626	553	352	877
6	280	849	749	478	1188
8	348	1053	930	592	1475
10	411	1245	1099	700	1743
15	557	1688	1489	949	2363
20	691	2094	1848	1178	2932
25	817	2476	2185	1393	3466
30	937	2838	2505	1597	3974
40	1162		3108	1981	4931
50	1374		3674	2342	5829
60	1575		4213	2685	6683
70	1768		4729	3014	7502
80	1955		5227	3332	8293
90	2135		5710	3640	9058
100	2311		6180	3939	9803
110	2482		6637	4231	10530

*NRC-74 equations modified by Payne (1965). Requirements by biological stage.

Caloric Needs of Dogs
Growth and Maintenance Worksheet

How much to feed: Feed freely (if and only if your dog self-regulates its feed intake), or calculate the needed amount as follows:

1.) Enter your dog's caloric needs as shown in the table "Caloric Needs for Given Biologic Stage": _____.

Each recipe lists the total calories and cup yields.

2.) Divide the calories by the needs of your dog by the average calories per cup to calculate the cups needed for your dog.

(caloric needs) ÷ (avg. calories per cup) = (cups needed for your dog)

The recipes on the next page have been included because they:

- perform a specific function
- illustrate the process of designing a dog food
- are consistent with the principles covered in Parts I through VI in this series
- have been tested extensively
- make sense and are not fad diets

(The authors and editors wish to thank Dr. Richard Pitcairn of the Animal Natural Health Center, Eugene, Ore., and Rodale Press, publishers of "Dr. Pitcairn's Complete Guide to Natural Health for Dogs and Cats." The revised edition of this book was due out in the fall of 1994.)

Conclusions: It is extremely important that you are careful when formulating a feed for your dog, or supplementing a commercial feed. There have been fads over the years of adding one vitamin or mineral after another to dog food. Sometimes the results have been disastrous. One particularly dangerous practice is calcium supplementation. We have yet in our research, and in our visits to supermarkets, feed stores, dog shows and pet stores, to find dog foods deficient in calcium.

Weight-Loss Diet for Dogs

Dogs can have a tendency to get overweight, especially if their folks cater to a sweet tooth. Feeding a marginal-quality commercial food can also be a factor; in an effort to get adequate vitamins, minerals and other nutrients, the dog may eat more and more. The goal in a weight-loss program is to use bran, vegetables and other high-fiber foods to help fill the stomach and assuage begging, while providing about 60 percent of the calories needed to maintain ideal weight. There must also be good-quality protein and nutrients, including a minimal but adequate amount of unsaturated fatty acids (found in vegetable oil).

- 1 cup ground or chunky lean beef heart or hamburger (or ground turkey or chicken)
- 1 cup uncreamed cottage cheese
- 2 cups oat or wheat bran
- 2 cups rolled oats
- 4 cups cooked carrots, broccoli, peas, green beans, corn or other vegetables (frozen or canned are OK)
- 4,000 milligrams calcium** (= 2 rounded tablespoons bone meal or 2¼ teaspoons eggshell powder)
- 1 to 2 teaspoons cold-pressed safflower, soy or corn oil
- 2 tablespoons nutritional yeast
- (optional) garlic or onion powder for flavoring
- Balanced dog vitamins, as recommended on label for ideal weight

Cook vegetables, using 3 to 4 cups water. When they are soft, add oats and bran. Cover and let sit for 10 minutes until oats are soft. Add remaining ingredients, stirring well. (Meat may be cooked.) Feed vitamins as directed on label. Determine your dog's ideal weight and feed two meals a day, together totalling these amounts: for an ideal weight of 10 pounds, feed about 2 cups; 25, about 4 cups; 40, about 5½ cups; 60, about 7½ cups; and 85, about 9¼ cups. Feed a little less if your dog is inactive and a little more if it's active. If you use more or less water in cooking, adjust the quantity fed accordingly. Make sure there is no access to other food, other than an occasional low-calorie snack such as a carrot stick or leftover vegetables. You can make this in quantity and freeze extras. Yield: about 12 cups.

Healthy Powder: = 2 cups nutritional yeast, 1 cup lecithin granules, ¼ cup kelp powder and 9,000 milligrams calcium (= ¼ slightly rounded cup bone meal or 5 teaspoons eggshell powder**). Optional: 1,000 milligrams vitamin C (= ¼ teaspoon sodium ascorbate) and/or ¼ teaspoon garlic powder.

** Calcium: The amount of powder or crushed tablets that will equal the milligrams of calcium is specified in each recipe. Or else use the indicated amounts of bone meal or eggshell powder. (To make eggshell powder: Rinse eggshells, bake at 350 degrees for 10 minutes. Grind to a fine powder. One teaspoon (about 1 shell) = approximately 1,800 milligrams of calcium from calcium carbonate.)

Susan's Maintenance Diet

- 6 cups white rice or oatmeal, cooked
- ½ pound ground round or 2 small cans all-tuna cat food*
- 2 to 3 eggs
- ½ cup plain yogurt
- 1 heaping teaspoon kelp powder
- 1 heaping teaspoon garlic powder

(* If not using the tuna, add 1 to 2 tablespoons cod liver oil.)

Cook the base cereal. While hot, add the eggs and uncooked meat (but not the tuna). Let cool and then mix in remaining ingredients. You can add leftover vegetables that have been put through a blender or food processor. Yield: feeds 3 medium-size adult dogs for 1 day.

Kidney Diet: Food for Older Dogs

When dogs age, their kidneys often begin to fail. The kidneys' job is to eliminate anything that is unuseable from the blood, so the goal of this diet is to lighten their load by providing minimal levels of protein, phosphorus and sodium in a maximally usable form. This creates minimal waste. By feeding a fresh diet, you can also eliminate artificial preservatives, flavorings and colorings. This recipe provides about 16 percent highly usable protein, with low sodium and phosphorus levels and high levels of B complex and vitamin A.

- ¼ pound (= ½ cup) regular (fatty) hamburger
- 2¾ cups cooked white rice, enriched**(1)** (= scant cup, uncooked)
- 1 medium or large egg
- 2 tablespoons chopped parsley, carrots, zucchini, green beans or preferred vegetable
- 2 tablespoons expeller-pressed safflower, soy or corn oil
- ⅛ teaspoon iodized salt (sodium chloride)**(1)**
- 600 milligrams calcium**(2)**
- Dog vitamins, providing 1 day's recommendation for a 40-pound dog
- (optional) 1 to 2 cloves garlic for flavor
- (optional) ⅛ to ¼ teaspoon potassium chloride (salt substitute)

Mix all ingredients together in a large bowl. Serve raw or cooked, whichever is more palatable. To cook, either braise the meat and then add the rest, or bake all together in a casserole dish for 20 to 30 minutes in a moderate oven. In addition to the food, be sure to provide plenty of fresh water at all times, preferably filtered or bottled. Yield: provides about 1,250 calories.

(1) Enriched white rice is more easily digested and has higher levels of needed iron and the major B vitamins, which are low in a reduced-meat diet. With less meat, the sodium level gets a bit too low, so a small amount of iodized salt is added. (If more saltiness is needed for flavor, use iodized potassium chloride, a salt substitute.)

(2) Avoid calcium supplements which contain phosphorus (calcium phosphate or bone meal) because they would make the level of phosphorus too high.

Healthy Foods for Puppies and Mother Dog

This recipe is based on rice and has a higher proportion of meat. It provides about 32 to 34 percent protein, depending on the variation choices (calculated on a dry weight basis). Yield: about 6¾ cups.

- 2 cups lean hamburger, ground lean beef heart or turkey
- 4 cups cooked brown rice (1⅓ cups before cooking)
- ½ cup vegetables
- 1 tablespoon cold-pressed (expeller-pressed) safflower, corn or soy oil.
- 2,500 IU vitamin A (with D)
- 1 tablespoon Healthy Powder
- 1 tablespoon yeast sprinkle
- 1,800 milligrams calcium
- 50 to 200 IU vitamin E (mixed tocopherols)

Cook the rice (and vegetables, unless finely grated) and add the meat and supplements when slightly cooled, to preserve nutrients. Or, if preferred, braise the meat and mix with the remaining ingredients. Variation: Occasionally omit the vitamin A and add 1 tablespoon liver.

Lean heart = 210 calories per cup; ground turkey = 220 calories per cup; lean hamburger = 255 calories per cup.

Supplements for Commercial Kibbles

To provide many of the benefits of fresh foods and extra nutrients with more convenience than fixing the entire diet, add fresh meat or dairy products, oil and food supplements, plus enough calcium to balance the high phosphorus in the meat. The resulting levels of quality protein, fatty acids, lecithin, B vitamins and minerals are especially helpful for skin and coat problems.

Fresh Meat Supplement

- 1 pound (2 cups) chopped or ground lean chuck, lean hamburger, turkey, chicken, lean beef heart or (occasionally) liver
- 4 teaspoons expeller-pressed vegetable oil
- 4 teaspoons Healthy Powder
- 50 to100 IU vitamin E (can be premixed with oil at 1,600 IU vitamin E per cup oil)
- 1,080 milligrams calcium (= 1¼ teaspoon bone meal or ½+ teaspoon eggshell powder)

Mix the oil and powders together. Then stir in the meat, coating it. Add ¼ cup to each cup kibble at mealtime (you'll feed proportionally less kibble). Alternate with the Dairy Supplement or else add 1,000 to 2,000 IU vitamin A supplement to the meat version. Yield: supplements 8 to 9 cups kibble.

Dairy Supplement

Eggs are one of the best and least expensive protein sources available, as well as a good source of vitamin A.

- 2 eggs (raw)
- 1 teaspoon expeller-pressed vegetable oil
- 1 teaspoon Healthy Powder
- 220 milligrams calcium (= ⅓ teaspoon bone meal or ⅛ teaspoon eggshell powder)

Mix the powders and oils and stir into 1 to 2 cups of kibble. Serve the eggs raw or cooked, either separately or mixed into the dry food. Larger quantities: To supplement 6 cups of kibble: use 9 eggs, 2 tablespoons oil, 2 tablespoons Healthy Powder and 1,980 milligrams calcium (= 1 tablespoon bone meal or 1 rounded teaspoon eggshell powder). Yield: supplements 1 to 2 cups kibble.

Calcium is cheap—expect it to be there in adequate quantities. Too much calcium will disrupt the very important calcium:phosphorus ratio. Do not, repeat do not, disrupt this ratio by unequally supplementing with calcium.

Recently, a fad has developed which suggests ingestion of high amounts of vitamin C. It is touted to prevent hip dysplasia, help ears stand, etc. The literature suggests that dogs require no exogenous source of vitamin C. Too much, on the other hand, will increase skeletal disease. If you must supplement heavily with a vitamin, we suggest vitamin E; at least it will help counteract the effect of synthetic antioxidants.

Susan Thorpe-Vargas and I agree with the nutritionists, physicians and vets we spoke to, that fad diets and supplements are definitely not the way to go.

References:

1. Personal conversation, September 22, 1993, with Dr. Al Plecknor, D.V.M., about book: "Pet Allergies: Remedies for an Epidemic."

2. Plecknor A., Zucker M., "Pet Allergies: Remedies for an Epidemic," J.P. World, Ltd., 1993.

3. "Nutrition Reviews: Present Knowledge in Nutrition," 5th Ed., New York, Van Nostrand Reinhold Co., 1981.

4. Kutsky, R.J., "Handbook of Vitamins, Minerals and Hormones," 2nd Ed., New York, Van Nostrand Reinhold Co., 1981.

5. White, Handler, Smith, "Principles of Biochemistry," 3rd Ed., New York, Van Nostrand Reinhold Co., 1981.

6. Lehniger, Albert, "Principles of Biochemistry," 2nd Ed., Worth Publishing, 1993.

7. Ibid.

8. Personal conversation with J. Spalholtz, September 27, 1993.

Part VIII

Home-cooked meals put you in charge of your dog's nutrition, but they can be costly and time-consuming to prepare

Conclusions from "Feed that dog! Part VII" (January 1994 issue): Homecooking for your dog is a viable alternative. Most dogs in the world, especially the Third World, and in the United States lived off of tablescraps until recently when commercial dog foods became available. Problems only arise when vitamin and mineral ratios get out of whack, or when the dog does not get a level of protein or calories sufficient for its level of activity and type of environment. A very real danger exists in reading fad literature and duplicating the concepts in home-brew dog food. Stick with the tried and proven.

We have been flooded with recipes. We were unaware that there were so many fanciers making food for their dogs. Many of the recipes received were for treats and supplements rather than for complete diets. One of the best books of treats was Wendy Boyd-Smith's "The No Barking at the Table Cookbook."[1] Of necessity, we have had to pick and choose from the recipes sent in, so only a few can be analyzed in this article.

While "make your own" sounds easy, in practice it is not necessarily that easy to formulate a complete and adequate diet and nutrition for your dog. NRC-74 remains the standard; however, there are many books out there with recommended formulations that do not even come close to being adequate by NRC-74 standards. In our research for this series, we looked at a number of books which claimed their recipes were complete nutrition for various given biological stages. As a consumer, you must conduct your own analysis and make your own decisions as to the completeness of a given recipe.

The following is the general approach to analyzing a recipe. The starting point is the NRC-74 requirements. You will not go wrong with NRC-74 guidelines. While it may be argued that those requirements are not 100 percent accurate and individual variances may be as much as 40 percent, you will still be in the ballpark. It is getting in the ballpark that counts.

We attempted to use several commercially available software programs to determine the nutritional content of the recipes presented. While there are many such programs available, they tend to be quite expensive, and we did not find any which adhered strictly to one standard of nutritional values. For the purposes of this article, we stayed with the Pennington revision of Bowes and Church's "Food Values of Portions Commonly Used," which has been the standard since the 1930s and is now in its 15th edition.[2] For those of you who decide to develop or analyze dog food recipes, be aware that there are a number of different sources of nutrient values, and that seldom do all sources agree exactly.

Because there was no adequate and affordable software immediately available and neither of us is handy or accurate with a calculator, we took the "academic" way out and created an ingredients list in Lotus 3.1 spreadsheet format and copied ingredients specs into templates for analyzing the various recipes presented.[3]

The second step is to determine if the ranges of nutrients and minerals and vitamins and trace elements in a recipe fall within the ranges suggested in Table 1 and Table 2.[4] Compare these tables with the requirements shown in Part I and Part II of this series. NRC-74 data are based upon research colony animals under minimal or no stress and a thermoneutral environment; Table 1 and Table 2 are based upon canine athletes and their requirements. Dog shows are probably equivalent to "brief exercise" but are certainly less than prolonged exercise. Be aware that there are dogs out there, just like humans, that have the capacity to "worry" off a great amount of weight. Unless an animal is being used daily for packing supplies in snow, being raced, etc., there would be absolutely no requirement to feed for Table 1 "endurance." There are individual exceptions, of course.

Author Cargill, in putting five Akitas and two Dobermans through quarantine (four months) in Hawaii, found that the social stress on the animals was manifested in only one of the Dobermans. He required a minimum of double rations to maintain weight, whereas his kennelmate, a female, became nearly obese on a standard ration and little exercise. We caution those of you in the fancy who read this series on canine nutrition to

Table 1. Nutritional Requirements by Excercise Level

Nutrient/Energy Source	NRC-74 Minimum mg/kg/day	Grandjean & Paragon Recommendations Adult Maintenance	Brief Exercise	Prolonged Exercise	Endurance
Energy (Kcal ME/Kg) exp.75*		132	150-190	200-400	400-800
Proteins (g/1000 Kcal ME)		50	70-80	80-90	80-90
Proteins (%ME)		20	30	35	35-40
Proteins (%DM)		20-27	30-35	35-40	35-40
Fats (%DM)	5	5-10	12-20	20-30	35-40
Fiber (%DM)**		2-5	3	2.5	2
Calcium (mg/kg)	119	200	250-300	300-400	400-500
Calcium (g/1000 Kcal ME)	1.6				
Calcium (%DM)		0.9-1.1	1.25-1.5	1.4-1.5	1.8-3.0
Phosphorus (mg/kg)	89	170	190-240	200-250	200-300
Phosphorous (mg/Kcal ME)	1.2				
Phosphorus (%DM)		0.7-0.9	1.0-1.2	1.0-1.3	1.0-1.5
Potassium (mg/kg)	89	130	130-150	150	150
Potassium (g/1000 Kcal ME)	1.2				
Potassium (%DM)		0.5-0.6	0.6-0.7	0.7	0.7
NaCl (mg/kg)		240	240	240	240
NaCl (%DM)		0.8-1.0	0.8-1.0	0.8-1.0	0.8-1.0
Magnesium (mg/kg)	8.2	8	20-25	25-30	25-30
Magnesium (g/1000 Kcal ME)	0.11				
Magnesium (%DM)		0.04	0.1	0.15	0.15
Midpoint Ratios:					
Calcium:Phosphorus (mg/kg)	1.2-1.4	1.18	1.28	1.56	1.80
Calcium:Phosphorus (%DM)		1.25	1.25	1.26	1.80
Sodium:Chloride	1.5				

* NRC-74 recommendation
** With exercise of short or medium duration, calcium intake must be slightly increased to prevent joint pain

Table 2. Limits to Vitamin & Trace Mineral Daily Intake

Vitamin/Trace Element	NRC-74* Minimum	Minimum	Optimum Range** Minimum	Optimum Range** Maximum	Maximum
Vitamin A (mg/kg)		61	76	110	610
Vitamin A (IU/kg)	76				
Vitamin A (IU/1,000 Kcal ME)	1011				
Vitamin D (mg/kg)		550	700	1050	5500
Vitamin D (IU/kg)	8				
Vitamin D (IU/1,000 Kcal ME)	110				
Vitamin E (mg/kg)		1200	1900	3600	24000
Vitamin E (IU/kg)	0.5				
Vitamin E (IU/1,000 Kcal ME)	6.1				
Vitamin K (mg/kg)			0	105	
Thiamin-B1 (mg/kg)		54	100	210	1620
Thiamin-B1 (mcg/kg)	20				
Thiamin-B1 (mg/1,000 Kcal ME)	0.27				
Riboflavin-B2 (mg/kg)		100	160	290	2000
Riboflavin-B2 (mcg/kg)	50				
Riboflavin-B3 (mg/1,000 Kcal ME)	0.68				
Niacin (mg/kg)		450	850	1800	13500
Niacin (mcg/kg)	225				
Niacin (mg/1,000 Kcal ME)	3				
Pantothenic acid (mg/kg)		400	750	1600	12000
Pantothenic acid (mcg/kg)	200				
Pantothenic acid (mg/kg)	2.7				
Pyridoxine-B6 (mg/kg)		60	110	230	1800
Pyridoxine-B6 (mcg/kg)	22				
Pyridoxine-B6 (mg/1,000 Kcal ME)	0.3				
Folic acid (mg/kg)		8	15	31	240
Folic acid (mcg/kg)	4				
Folic acid (mg/1,000 Kcal ME)	0.054				
Vitamin B12 (mg/kg)		1	1.9	3.9	30
Vitamin B12 (mcg/1,000 Kcal ME)	0.5				
Vitamin B12 (mcg/kg)	7				
Choline (mg/kg)	25	50	53	60	150
Choline (mg/1,000 Kcal ME)	340				
Iron (mg/kg)	0.65	1.7	2.3	3.5	20
Iron (mg/1,000 Kcal ME)	8.7				
Copper (mg/kg)	0.65	0.16	0.5	1.4	12.5
Copper (mg/1,000 Kcal ME)	8.7				
Zinc (mg/kg)	0.72	1.9	3.3	6.7	50
Zinc (mg/1,000 Kcal ME)	9.7				
Iodine (mg/kg)	0.012	0.03	0.05	0.09	0.64
Iodine (mg/1,000 Kcal ME)	0.16				
Manganese (mg/kg)	0.28	0.28	1	2.8	25
Manganese (mg/1,000 Kcal ME)	1.4				
Selenium (mg/kg)		0.006	0.013	0.025	0.25
Selenium (mcg/kg)	2.2				

* NRC-74 minimums for growth
** Minimum, Maximum, Optimum values proposed by Grandjean & Paragon

always be aware of individual variances. The real test, scientific theories notwithstanding, is the clinical presentation and condition of an animal given its environment, stress level and amount of physical exercise.

The tables presented contain various units of measurement; there are several ways of stating nutritional requirements or content. The analyses presented are stated in terms of percentage of calories: percentage of calories derived from fat, carbohydrates and proteins. The Grandjean and Paragon requirements are also stated this way so comparison is easy. Many commercial foods are stated in an unspecified mixture of dry and wet weights, which makes comparisons virtually impossible.[5]

If you find that a recipe meets your needs, that is, it is in the ballpark for caloric, vitamin and mineral requirements, you may still wish to make changes. The third step is to substitute various ingredients in varying quantities to suite your preference, what you are willing to pay for ingredients and local availability. Another very good reason for substituting ingredients is to get away from ingredients to which your dog is allergic. Amounts of individual ingredients may need to be varied to obtain the appropriate ratios such as the all-important calcium:phosphorus (Ca:P) ratio. Table 3 provides a listing of ingredients commonly found in home-brew foods. Be aware that there is a variance between lots of grains, nutrient values of various meats, etc. The meat from any two cows, even from the same herd and pre-slaughter feed lot, will not have the same nutritional value. Therefore, any values given are only approximations. For more complete listings, we suggest United States Department of Agriculture sources.[6,7]

In most cases the following concepts and guidelines have proven satisfactory:

• Red meats, organs, cheese, corn, soy, sorghum and other grains tend to be high in phosphorus and must be supplemented with calcium to preserve a 1.3:1.0 calcium:phosphorus ratio. Do not skip this step. There are venial sins and there are cardinal sins; failing to preserve a proper calcium:phosphorus ratio is a cardinal sin. You and your animals will pay dearly in terms of skeletal disease if you violate this principle.

• Corn meal, soy meal, wheat and rice flour are staples of life. Note the 400+ calories per cup that characterizes these few ingredients. Note especially the high protein content of soy, but remember, some dogs have difficulty digesting soy. Contrary to some of the advertising hype, soy is not bad. It is just that some dogs do not thrive on soy, whereas others do. Remember, there are humans (and dogs) who cannot tolerate a glass of milk. That does not in and of itself make milk bad; neither does the occasional dog's inability to adjust to soy make soy in and of itself bad.

• Cheap meat with high nutritional value is not an oxymoron. Chicken leg quarters and turkey leg quarters with skin can usually be had for 39 to 49 cents per pound. This is almost as good as owning a slaughterhouse. The dog fancy is expensive enough as it is; chicken is one of the best cost-containment solutions. Unfortunately, it does nothing for airfares or handling fees.

• Organ meat in large quantities can also be inexpensive; however, few dogs can tolerate a great deal of organ meat. One quick look at Table 3 should demonstrate that organ meat is a relatively potent nutrient. Remember, also, that kidneys and liver tend to concentrate the not so-good-for-you pesticides and antioxidants used as preservatives. A little liver will go a long way. Remember to be prepared to supplement with calcium if you use organ meats as ingredients.

• Vegetables are not just for wimpy dogs with poor dentition whose owners eat quiche. Beans and peas are high in calories and in protein and fiber. Dogs in this hemisphere and around much of the world have lived very successfully for millennia on beans, corn grits and rice. Dried split peas and various beans are inexpensive, especially when purchased in 100-pound bags. This might be a good time to reflect on the origin of "hush puppies."

The recipes in this article have all been submitted by readers who swear by them. I have not adjusted them significantly other than to show the amount of calcium supplementation required to preserve the NRC-74 calci-

Table 3. Ingredients commonly used in dog foods

Ingredient	Recipe Amounts QTY	Units	Database QTY	Units	Calories	Protein g	Carbohydrate g	Fat g	A RE	A IU	C mg	D mg	B1 mg	B2 mg	Niacin mg	B6 mg	B12 mcg	Folate mcg	Panto mg	Na mg	K mg	Ca mg	P mg	Mg mg	Fe mg	Zn mg
MEATS:																										
Beef, 70% lean	3.5	oz	100	g	287	23	0	20.9					0.03	0.16	4.8	0.23	2.34	9	0.22	60	221	10	137	15	2.41	4.89
Beef, 80% lean	3.5	oz	100	g	268	23.9	0	18.3					0.05	0.19	4.3	0.2	1.77	9	0.27	56	224	9	128	17	2.09	5.1
Beef, 90% lean	3.5	oz	100	g	250	24.5	0	16.1					0.04	0.24	4.2	0.52	1.73	9	0.27	49	224	7	124	17	2.28	5.34
Chicken Leg w/Skin	1	ea	114	g	265	29.6	0	15.4	45	154	0		0.08	0.24	5.7	0.23	0.25	8	1.02	99	256	14	99	26	1.52	2.96
Lamb, ground	1	lb	454	g	1150	70	0	95	0		0	0	0.38	0.76	15.6	0.38		85		918	788	34		84	5.7	11.8
Turkey, leg w/skin	3.5	oz	100	g	221	27.5	0	11.5	0	0	0		0.06	0.24	3.5	0.32	0.36	9	1.16	76	274	33	196	23	2.27	4.16
ORGANS:																										
Beef, kidney	3.5	oz	100	g	144	25.5	1	3.4	373	1241	1		0.19	4.06	6	0.52	51.3	96	1.69	134	179	17	308	18	7.31	4.22
Beef, liver	3.5	oz	100	g	161	24.4	3.4	4.9	10602	35679	23		0.2	4.1	10.7	0.91	71	217	4.57	70	235	7	404	20	6.77	6.07
Chicken, liver	3.5	oz	100	g	157	24.4	0.9	5.5	4913	16375	16		0.15					770		51	140	14	312	21	8.47	4.34
DAIRY PRODUCTS, EGGS:																										
Cheese, cottage, creamed	1	cup	210	g	217	26.2	5.6	9.5	101	342	0		0.04	0.34	0.3	0.14	1.31	26	0.45	850	177	128	277	11	0.29	0.78
Egg, whole, large	1	ea.	50	g	79	6.1	0.6	5.6	78	260	0		0.04					24		69	65	28	90	8	1.04	0.72
Milk, evaporated, whole	1	oz	32	g	42	2.1	3.2	2.4	17	77	1		0.02					2		33	95	82	64	8	0.06	0.24
Milk, powdered, whole	0.25	cup	32	g	159	8.4	12.3	8.6	90	295	3		0.09					12		119	428	282	248	27	0.15	1.07
Milk, whole, 3.5% fat	8	fl oz	244	g	150	8	11	8	80	22	5		0.1	0.42	0.2	0.02	1.34	37	0.85	122	351	288	227	24	0.12	0.93
Yogurt, plain, non-fat	8	oz	227	g	144	11.9	16	3.5	36	150	2		0.1					25		159	531	415	328	40	0.18	2.02
GRAINS:																										
Barley, medium pearl	0.25	cup	48	g	172	5.5	36.3	0.5					0.11	0.06	2.2	0.13	0	32	0	5	130	11	113	34	1.24	0
Bulgar	0.5	cup			76	2.8	17	0.2	0	0	0	0	0.05	0.026	0.9	0.076	0	17		187	82	9		29	0.88	0.52
Corn flour	1	cup	117	g	431	9.1	89.9	3		400	0		0.23	0.07	1.6					1		7	92		2.1	
Corn grits	1	oz	28	g	101	2.4	22.4	0.2	0	161			0.12	0.07	1	0.05	0	3	0	1	45	1	20	8	0.81	0
Corn meal, yellow, ground	1	cup	122	g	433	11.2	89.9	4.8	0	620	0		0.46	0.13	2.4					1	346	24	312		2.9	
Farina/creamed wheat	0.75	cup	175	g	87	2.5	18.5	0.1		0			1.2	0.09	1	0.02	0	4	0.1	1	22	3	21	3	0.88	0.12
Oatmeal	0.33	cup	28	g	109	4.6	18.4	1.9		0			0.19	0.03	0.2	0.06	0	29	0	1	105	14	128	40	1.08	1
Oatmeal, cooked	0.75	cup	175	g	108	4.5	18.9	1.8	0	29			0.19	0.04	0.2	0.04	0.04	7	0.35	1	99	15	133	42	1.19	0.86
Rice, brown, cooked	1	cup	195	g	232	4.9	49.7	1.2	0	0	0		0.18	0.04	2.7		0			560	137	23	142		1	
Rice, flour	1	cup	113	g	398	7.1	91	0.9		0	0		0.52	0.59	2.9					45	188	13	249	60	3.28	
Rice, white, cooked	1	cup	205	g	223	4.1	49.6	0.2		0	0		0.23	0.02	2.1					767	57	21	57		1.8	
Sorghum grain	3.5	oz	100	g	332	11	73	3.3		0	0		0.38	0.15	3.9						350	28	287		4.4	
Soybean flour	1	cup	85	g	368	32.1	27.1	17.6	10	102	0		0.49	0.99	3.7	0.39	0	283	1.35	11	2138	175	420	364	5.42	3.33
Soybean meal, de-fatted	1	cup	122	g	411	60	43.8	2.9	5	48	0		0.84	0.31	3.2	0.69	0.69	369	2.41	3	3038	297	855	373	16.71	6.17
Wheat flour, whole	1	cup	120	g	400	16	85.2	2.4			0		0.66	0.14	5.2					4	444	49	446		4	
Wheat germ, toasted	1	oz	28	g	108	8.3	14.1	3			2		0.47	0.23	0.16	0.28		100	0.39	1	268	13	325	91	2.58	4.73
Wheat, whole, cooked	0.75	cup	182	g	113	3.7	24.9	0.7		0			0.13	0.09	1.6	0.05	0	19	0.3	1	129	13	126	40	1.13	0.87
VEGETABLES:																										
Beans, navy, dry	1	cup	182	g	259	15.8	47.9	1	0		2		0.37	0.11	1	0.3	0	255	0.46	2	869	128	285	107	4.51	1.93
Beans, pinto, dry	1	cup	171	g	235	14	43.9	0.9	0		4		0.32	0.16	0.7	0.27	0	294	0.49	3	800	82	273	95	4.47	1.85
Beets, boiled	0.5	cup	85	g	26	0.9	5.7	0	1	11			0.03	0.01	0.2	0.03	0	45	0.08	42	266	9	26	31	0.53	0.21
Broccoli, raw	0.5	cup	44	g	12	1.3	2.3	0.2	68	678			0.03	0.05	0.3	0.07	0	31	0.24	12	143	21	29	11	0.89	0.12
Carrot, raw	1	med	72	g	31	0.7	7.3	0.1	2025	20253			0.07	0.04	0.73	0.11	0	10	0.14	25	233	19	32	11	0.36	0.14
Onion, raw	0.5	cup	80	g	27	0.9	5.9	0.2	0				0.05	0.01	0.1	0.13	0	16	0.11	2	124	20	23	8	0.29	0.14
Peas & carrots, frozen	0.5	cup	90	g	40	2.5	8.1	0.3	621	6209	7		0.18	0.05	0.9	0.07	0	21	0.13	55	127	18	39	13	0.75	0.36
Peas, split, boiled	1	cup	198	g	231	16.4	41.4	0.8	1	14			0.37	0.11	1.7	0.09	0	127	1.17	4	710	26	195	71	2.52	1.96
Potato, w/skin, baked	1	med	202	g	220	4.7	51	0.02					0.22	0.07	3.3	0.7	0	22	1.12	16	844	20	115	55	2.75	0.65
Sweet potato, baked	1	med	114	g	118	2	27.7	0.1	2488	24877			0.08	0.15	0.7	0.28	0	26	0.74	12	397	32	62	23	0.52	0.33
Tomato, puree	1	cup	250	g	102	4.2	25.1	0.3	340				0.18	0.14	4.3	0.38	0		1.1	49	1051	37	99	60	2.32	0.54
Tomato, whole	1	ea	123	g	24	1.1	5.33	0.3	139				0.07	0.06	0.7	0.06	0	12	0.3	10	254	8	29	14	0.59	0.13
MISCELLANEOUS:																										
Brewer's yeast	1	oz	28	g	80	11	10.9	0.3					4.43	1.21	10.7					34	537	60	497		4.9	
Garlic, clove	3	ea	9	g	13	0.6	3	0.1					0.02	0.01	0.1		0		0	2	36	16	14	2	0.15	
Honey	1	tbl	21	g	64	0.1	17.3	0					0	0.01	0.1					1	11	1	1		0.1	
Lard	1	tbl	13	g	115	0	0	12.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01
Oil, corn	1	tbl	14	g	120	0	0	13.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil, olive	1	tbl	14	g	119	0	0	13.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0.01
Oil, peanut	1	tbl	14	g	130	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil, vegetable	1	tbl	13	g	115	0	0	12.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01
Sugar, brown	1	cup	145	g	541	0	139.8	0					0.01	0.04	0.3					44	499	123	28		4.9	
Sugar, white, granulated	1	cup	200	g	770	0	199	0					0	0	0					2	6				0.2	
Syrup, corn	1	tbl	21	g	59	0	15.4	0					0	0	0					14	1	9	3		0.8	
Syrup, karo, light	1	tbl	21	g	60	0	14.9													30						
Syrup, molasses, blackstrap	1	tbl		g	43	0	11	0					0.02	0.04	0.04					19	585	137	17		3.2	

Terri McGinnis, DVM "Homemade Diet for Dogs I"

Ingredient	Recipe Amounts QTY	Units	Conv. factor	Database QTY	Units	Calories	Protein g	Carbohydrate g	Fat g	A RE	A IU	C mg	D mg	B1 mg	B2 mg	Niacin mg	B6 mg	B12 mcg	Folate mcg	Pant mg	Na mg	K mg	Ca mg	P mg	Mg mg	Fe mg	Zn mg
Farina/creamed wheat 490g	0.75	cup		175	g	87	3	19	0		0			1.20	0.09	1.00	0.02	0.00	4.00	0.10	1.00	22.00	3.00	21.00	3.00	0.88	0.12
Extended			2.80	490	g	244	7	52	0	0		0.00	0.00	3.36	0.25	2.80	0.06		11.20		2.80	61.60	8.40		8.40	2.46	0.34
Cheese, cottage, crmd 340g	1	cup		210	g	217	26	6	10	101	342	0.00		0.04	0.34	0.30	0.14	1.31	26.00	0.45	850.00	177.00	126.0	277.0	11.00	0.29	0.78
Extended			1.62	340	g	351	42	9	16	164	554	0.00	0.00	0.06	0.55	0.49	0.23	2.12	42.10	0.73	1376.19	286.57	204.0	448.5	17.81	0.47	1.26
Egg, whole, large	1	ea.		50	g	79	6	1	6	78	260	0.00		0.04					24.00		69.00	65.00	28.00	90.00	6.00	1.04	0.72
Extended			1.00	50	g	79	6	1	6	78	260	0.00	0.00	0.04	0.00	0.00	0.00	0.00	24.00	0.00	69.00	65.00	28.00	90.00	6.00	1.04	0.72
Sugar, white, granulated 45g	1	cup		200	g	770	0	199	0					0.00	0.00	0.00					2.00	6.00				0.20	
Extended			0.23	45	g	173	0	45	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	1.35	0.00	0.00	0.00	0.05	0.00
Oil, corn 1 tbl	1	tbl		14	g	120	0	0	14	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Extended			1.00	14	g	120	0	0	14	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brewer's yeast 25g	1	oz		28	g	80	11	11	0					4.43	1.21	10.70					34.00	537.00	60.00	497.0		4.90	
Extended			0.89	25	g	71	10	10	0	0	0	0.00	0.00	3.96	1.08	9.55	0.00	0.00	0.00	0.00	30.36	479.46	53.57	443.8	0.00	4.38	0.00
			Total	964		1039	65	116	35	242	814	0.00	0.00	7.42	1.88	12.84	0.28	2.12	77.30	0.73	1478.80	893.99	294.0	962.2	32.21	8.39	2.32
	Kcal per lb.					472																					
	Kcal per kg					1077																					
	Source of calories					100%	30.2%	53.6%	16.2%																		
	NRC-74 growth minimum/1,000 kcal						29		16	1011		0.00	110	0.27	0.68	3.00	0.30		54.00		0.15	1.20	1.60	1.20	0.11	8.70	9.70
	NRC-74 unit/1,000 kcal					g		g	IU			na	IU	mg	mg	mg	mg		mcg		g	g	g	g	g	mg	mg
	Recipe/1,000 kcal						63		34	233	783	0.00	0.00	7.14	1.81	12.36	0.27	2.04	74.42	0.70	1423.82	860.76	283.0	945.7	31.01	8.08	2.23
	x times NRC-74 growth min/1,000 kcal						2.2		2.1	0.2			0.0	26.5	2.7	4.1	0.9		1.4		9492.1	717.3	176.9	788.1	261.9	0.9	0.2

Body Weight	NRC-74 Kcal	Food kg
10 kg	742 kcals	0.7
20 kg	1248 kcals	1.2
30 kg	1692 kcals	1.6
40 kg	2100 kcals	1.9
50 kg	2482 kcals	2.3

	Recipe	NRC-74
Ratios: CA:P	0.3	1.3
Supplement Required:	Ca	1.0 g

Body Weight	NRC-74 Kcal	Food lb.
22 lb.	742 kcals	1.6
44 lb.	1248 kcals	2.6
66 lb.	1692 kcals	3.6
88 lb.	2100 kcals	4.4
110 lb.	2482 kcals	5.3

Maintenance Diet 1370 g/day for 30kg Greyhound (Grandjean & Paragon, Nutrition of Racing and Working Dogs, Part III.)

Ingredient	Recipe Amounts QTY	Units	Conv. factor	Database QTY	Units	Calories	Protein g	Carbohydrate g	Fat g	A RE	A IU	C mg	D mg	B1 mg	B2 mg	Niacin mg	B6 mg	B12 mcg	Folate mcg	Pant mg	Na mg	K mg	Ca mg	P mg	Mg mg	Fe mg	Zn mg
Beef, 90% lean 450g	3.5	oz		100	g	250	24.5	0.0	16.1					0.04	0.24	4.20	0.52	1.73	9.00	0.27	49.00	224.00	7.00	124.0	17.00	2.28	5.34
Extended			4.50	450	g	1125	110.3	0.0	72.5	0.0	0.0	0.00	0.00	0.18	1.08	18.90	2.34	7.79	40.50	1.22	220.50	1008.0	31.50	558.0	76.50	10.26	24.03
Rice, white, cooked 750g	1	cup		205	g	223	4.1	49.6	0.2			0.00		0.23							767.00	57.00	21.00	57.00		1.80	
Extended			3.66	750		816	15.0	181.5	0.7	0.0	0.0	0.00	0.00	0.84	0.00	0.00	0.00	0.00	0.00	0.00	2806.10	206.64	76.83	206.5	0.00	6.59	0.00
Peas, split, boiled 60g	1	cup		196	g	231	16.4	41.4	0.8	1.0	14.0			0.37	0.11	1.70	0.09	0.00	127.0	1.17	4.00	710.00	26.00	195.0	71.00	2.52	1.96
Extended			0.31	60		71	5.0	12.7	0.2	0.3	4.3	0.00	0.00	0.11	0.03	0.52	0.03	0.00	38.88	0.36	1.22	217.35	7.96	59.69	21.73	0.77	0.60
Carrot, raw 60g	1	med		72	g	31	0.7	7.3	0.1	2025	20253			0.07	0.04	0.73	0.11	0.00	10.00	0.14	25.00	233.00	19.00	32.00	11.00	0.36	0.14
Extended			1.00	72		31	0.7	7.3	0.1	2025	20253	0.00	0.00	0.07	0.04	0.73	0.11	0.00	10.00	0.14	25.00	233.00	19.00	32.00	11.00	0.36	0.14
Oil, corn 10g	1	tbl		14	g	120	0.0	0.0	13.6	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Extended			0.71	10		86	0.0	0.0	9.7	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Total	1342	g	2126	131.0	201.4	83.2	2025	20267	0.00	0.00	1.20	1.16	20.16	2.48	7.79	89.38	1.71	3062.82	1666.9	136.3	858.2	109.2	17.98	24.77
	Kcal per lb.					721																					
	Kcal per kg					1586																					
	Source of calories					100%	31.5%	48.5%	20.0%																		
	NRC-74 growth minimum/1,000 kcal						28.6		16.3		1011	0.00	110	0.27	0.68	3.00	0.30	7.00	54.00	2.70	0.15	1.20	1.60	1.20	0.11	8.70	9.70
	NRC-74 unit/1,000 kcal						g	g	g	RE	IU	na	IU	mg	mg	mg	mg	mcg	mcg	mg	g	g	g	g	g	mg	mg
	Recipe/1,000 kcal						61.5	94.6	39.1	961.6	9618	0.00	0.00	0.57	0.64	9.47	1.16	3.66	42.00	0.01	1434.41	783.21	63.67	403.3	51.33	8.45	11.64
	x times NRC-74 growth min/1,000 kcal						2.1		2.4		9.4		0.0	2.1	0.8	3.2	3.9	0.5	0.8	0.0	9562.7	652.7	39.7	336.0	466.6	1.0	1.2

Body Weight	NRC-74 Kcal	Food kg
10 kg	742 kcals	0.5
20 kg	1248 kcals	0.8
30 kg	1692 kcals	1.1
40 kg	2100 kcals	1.3
50 kg	2482 kcals	1.6

	Recipe	NRC-74
Ratios: CA:P	0.2	1.3
Supplement required:	Ca	1.0 g

Body Weight	NRC-74 Kcal	Food lb.
22 lb.	742 kcals	1.0
44 lb.	1248 kcals	1.7
66 lb.	1692 kcals	2.3
88 lb.	2100 kcals	2.9
110 lb.	2482 kcals	3.4

Rosemary's Farm -- Hypoallergenic Diet

Ingredient	Recipe Amounts QTY	Units	Conv. factor	Database QTY	Units	Calories	Protein g	Carbohydrate g	Fat g	A RE	A IU	C mg	D mg	B1 mg	B2 mg	Niacin mg	B6 mg	B12 mcg	Folate mcg	Pant mg	Na mg	K mg	Ca mg	P mg	Mg mg	Fe mg	Zn mg
Lamb, ground 4 oz	1	lb		454	g	1150	70	0	96	0		0	0	0.38	0.76	15.6	0.38		66		918	788	34		84	5.7	11.8
Extended			0.25	113	g	287.5	17.5	0	23.8	0	0	0	0	0.1	0.19	3.9	0.1	0	16.3	0	229.5	197	8.5	0	21	1.43	2.95
Rice, white, cooked 1 cup	1	cup		205	g	223	4.1	49.6	0.2		0	0		0.23	0.02	2.1					767	57	21	57		1.8	
Extended			1.00	205	g	223	4.1	49.6	0.2	0	0	0	0	0.23	0.02	2.1	0	0	0	0	767	57	21	57	0	1.8	0
Oil, corn 1 tsp	1	tbl		14	g	120	0	0	13.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Extended			0.50	7	g	60	0	0	6.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Total	326	g	571	22	50	31	0	0	0	0	0	0	6	0	0	16	0	997	264	30	67	21	3	3
	Kcal per lb.					797																					
	Kcal per kg					1753																					
	Source of calories					100%	21.2%	48.7%	30.2%																		
	NRC-74 growth minimum/1,000 kcal						28.64		16.30		1011	0.00	110.0	0.27	0.68	3.00	0.30	7.00	54.00	2.70	0.15	1.20	1.60	1.20	0.11	8.70	9.70
	NRC-74 unit/1,000 kcal						g	g	g	RE	IU	na	IU	mg	mg	mg	mg	mcg	mcg	mg	g	g	g	g	g	mg	mg
	Recipe/1,000 kcal						7.96	18.32	11.36	0	0	0.00	0.00	0.12	0.06	2.22	0.04	0.00	6	0.00	368.02	93.81	10.89	21.05	7.76	1.19	1.09
	x times NRC-74 growth min/1,000 kcal						0.3		0.7		0.0		0.0	0.4	0.1	0.7	0.1	0.0	0.1	0.0	2453.5	78.2	6.8	17.5	70.5	0.1	0.1

Body Weight	NRC-74 Kcal	Food kg
10 kg	742 kcals	0.5
20 kg	1248 kcals	0.8
30 kg	1692 kcals	1.1
40 kg	2100 kcals	1.4
50 kg	2482 kcals	1.7

	Recipe	NRC-74
Ratios: CA:P	0.5	1.3
Supplement required:	Ca	0.06 g

Body Weight	NRC-74 Kcal	Food lb.
22 lb.	742 kcals	1.1
44 lb.	1248 kcals	1.8
66 lb.	1692 kcals	2.5
88 lb.	2100 kcals	3.1
110 lb.	2482 kcals	3.7

Carol's Canine "Doggy Stew" (Carol Barfield)

Ingredient	Recipe Amounts QTY	Units	Conv. factor	Database QTY	Units	Calories	Protein g	Carbohydrate g	Fat g	A RE	A IU	C mg	D mg	B1 mg	B2 mg	Niacin mg	B6 mg	B12 mcg	Folate mcg	Pant mg	Na mg	K mg	Ca mg	P mg	Mg mg	Fe mg	Zn mg
Beef, 90% lean 1.5 lb.	3.5	oz		100	g	250	26	0.0	16					0.04	0.24	4.20	0.52	1.73	9.00	0.27	49.00	224.00	7.00	124.0	17.00	2.28	5.34
Extended			4.50	450		1125	110	0.0	72.5	0	0	0.00	0.00	0.18	1.08	18.90	2.34	7.79	40.50	1.22	220.50	1008.0	31.50	558.0	76.50	10.26	24.03
Chicken, liver 1 lb.	3.5	oz		100	g	167	24	0.9	5.5	4913	16375	16.00		0.15					770.0		51.00	140.00	14.00	312.0	21.00	8.47	4.34
Extended			3.66	366		574	89	3.3	20.1	17974	59909	58.54	0.00	0.55	0.00	0.00	0.00	0.00	2817	0.00	186.59	512.20	51.22	1141	76.83	30.99	15.88
Peas & carrots, frozen 1 lb.	0.5	cup		90	g	40	3	8.1	0.3	621	6209	7.00		0.18	0.06	0.90	0.07	0.00	21.00	0.13	55.00	127.00	18.00	39.00	13.00	0.75	0.36
Extended			5.04	454		202	13	40.8	1.51	3130	31293	35.28	0.00	0.91	0.26	4.54	0.36	0.00	106	0.66	277.19	640.07	90.72	196.6	65.52	3.78	1.81
Carrot, raw 3ea	1	med		72	g	31	1	7.3	0	2025	20253			0.07	0.04	0.73	0.11	0.00	10.00	0.14	25.00	233.00	19.00	32.00	11.00	0.36	0.14
Extended			3.00	216		93	2	21.9	0.3	6075	60759	0.00	0.00	0.21	0.12	2.19	0.33	0.00	30.00	0.42	75.00	699.00	57.00	96.00	33.00	1.08	0.42
Tomato, puree 29oz	1	cup		250	g	102	4	26.1	0.3	340				0.18	0.14	4.30	0.38	0.00		1.10	49.00	1061.0	37.00	99.00	60.00	2.32	0.64
Extended			3.63	906		370	15	91.0	1.09	1233	0	0.00	0.00	0.65	0.51	15.59	1.38	0.00	0.00	3.99	177.63	3809.9	134.1	358.9	217.5	8.41	1.96
Barley, medium pearl .25 cup	0.25	cup		48	g	172	6	36.3	0.5					0.11	0.06	2.20	0.13	0.00	32.00	0.00	5.00	130.00	11.00	113.0	34.00	1.24	0.00
Extended			2.00	96		344	11	72.6	1	0	0	0.00	0.00	0.22	0.12	4.40	0.26	0.00	64.00	0.00	10.00	260.00	22.00	226.0	68.00	2.48	0.00
Garlic, clove	3	ea		9	g	13	1	3.0	0.1					0.02	0.01	0.10			0.00		2.00	36.00	16.00	14.00	2.00	0.16	
Extended			1	9		13	1	3.0	0.1	0	0	0.00	0.00	0.02	0.01	0.10	0.00	0.00	0.00	0.00	2.00	36.00	16.00	14.00	2.00	0.16	0.00
			Total	2488	g	2708	240	229.6	96	26412	151960	93.82	0.00	2.72	2.06	45.61	4.66	7.79	3067	6.28	946.90	6929.1	386.6	2577	537.3	57.00	44.10
	Kcal per lb.					495																					
	Kcal per kg					1088																					
	Source of calories					100%	42.4%	40.6%	17.0%																		
	NRC-74 growth minimum/1,000 kcal						29		16.30		1011	0.00	110	0.27	0.68	3.00	0.30	7.00	54.00	2.70	0.15	1.20	1.60	1.20	0.11	8.70	9.70
	NRC-74 unit/1,000 kcal						g	g	g	RE	IU	na	IU	mg	mg	mg	mg	mcg	mcg	mg	g	g	g	g	g	mg	mg
	Recipe/1,000 kcal						89	84.8	35.63	10493	56121	34.65	0.00	1.00	0.77	15.86	1.72	2.88	1129	2.32	349.70	2659.0	142.8	951.7	198.4	21.06	16.29
	x times NRC-74 growth min/1,000 kcal						3.1		2.2		5.5		0.0	3.7	1.1	5.6	5.7	0.4	20.9	0.9	2331.4	2132.5	89.2	793.1	1804	2.4	1.7

Body Weight	NRC-74 Kcal	Food kg
10 kg	742 kcals	0.7
20 kg	1248 kcals	1.1
30 kg	1692 kcals	1.6
40 kg	2100 kcals	1.9
50 kg	2482 kcals	2.3

	Recipe	NRC-74
Ratios: CA:P	0.2	1.3
Supplement required:	Ca	3.0 g

Body Weight	NRC-74 Kcal	Food lb.
22 lb.	742 kcals	1.5
44 lb.	1248 kcals	2.5
66 lb.	1692 kcals	3.4
88 lb.	2100 kcals	4.2
110 lb.	2482 kcals	5.0

um:phosphorus ratio. Three written sources of recipes in addition to those already mentioned are especially fruitful and worthy of being in any fancier's "dog" library.[8,9,10]

So that you get the concept of the analysis, let's walk through one of the recipe analysis worksheets, step by step.

• The headings at the top of each recipe sheet are broken down into separate sections: ingredient; quantities and common measurements; calories, grams of protein, carbohydrates and fat; vitamins; and lastly, minerals. Note that the Database units are in grams of weight, whereas the recipe quantity and units may be in ounces, grams, pounds, cups, tablespoons, etc. When you read recipes, be aware that you are immediately thrust into the business of converting from one unit of measurement to another. Be especially careful of volume to weight conversions, because they vary with the density of the ingredient being considered.

• For ease in doing the analysis with a spreadsheet, we have included a conversion factor to change from units called for in the recipe to grams in the amounts in the database. For example, in the Grandjean and Paragon maintenance diet for Greyhounds, 750 grams of white rice is 3.66 times the 205 grams measurement in the Database for cooked white rice. The "Extended" line beneath each ingredient is the actual amount that goes into the recipe after all the conversions are said and done.

• The total amount of recipe made is given in grams and calories. These are the numbers from which portions to feed are derived.

• For purposes of comparison, potency of feed, assuming overall feed is of the same biologic value, is expressed in kcal (kilocalories) per pound or kcal per kilogram. These are the numbers you will need in order to determine daily rations for a given weight of animal.

• A short table in 10 kg increments of body weight is given for each recipe with the NRC-74 standard in kcals and an associated amount of dog food to feed in kilograms. For those who weigh their dogs in pounds and feed in pounds, the same feeding schedule chart is reproduced to the bottom right of the chart in pounds.

• The very bottom line of each analysis "x times NRC-74 growth min/1,000 kcal" is the "truth teller" concerning the recipe presented. Note that a 1:1 or better ratio with the NRC-74 growth minimum requirement in each vitamin and mineral category is a good indication that the recipe analyzed will be adequate. Do not be overly concerned about excesses. Sure, you pay for those excesses with more expensive urine and feces, but remember that the NRC-74 values are minimums which must absolutely be met even under the most benign circumstances of environment and condition.

• One very important consideration, especially if red meats or organs are used as main ingredients, is calcium supplementation. Note the calcium:phosphorus ratio of the recipe and the amount of calcium supplementation required to bring the ratio up to the NRC-74 recommended ratio of 1.3 to 1.0. We left the calcium supplement out of the recipes because there are many ways in which to get calcium into the diet. Be aware that "dolomite," of health food store fame, is a rock which dissolves extremely slowly. Could this be one reason why it is used to buffer Ph in marine aquariums? It dissolves just as slowly in the gut. Therefore, very little calcium from dolomite gets taken up into the system, but it does wonders for your soil after the earthworms have processed it.

• Bone meal works quite well, but is composed of calcium *and* phosphorus. If you use bone meal as your source of supplemental calcium, be sure to figure in the additional phosphorus! Some commercially available bone meal has a calcium:phosphorus ratio of 0.3. In our opinion, since calcium is cheap and not much is needed, go for the straight calcium powder. With commercial feeds, the calcium:phosphorus ratio should already be set to the proper level. As we have emphasized before, failure to maintain a 1.33 to 1.00 calcium:phosphorus ratio leads to disaster. It is beyond the scope of this series of articles to go into the specifics. Re-read Part II of this series if you have questions. One last parting shot before we get off the calcium:phosphorus bandwagon: Once you lose the calcium:phosphorus ratio, the requirement for vitamin D increases.

Conclusion: It is indeed possible to develop home-cooked dog foods that are entirely adequate and free of preservatives. However, there is an element of risk and a very big element of time, effort and expense. We repeat our statement made earlier in one of the previous articles: If you want your dog to eat as well as you do, the cost will be the same as feeding another member of the family and the time of preparation will not be significantly less. Many fanciers have found the solution is to use a chicken or turkey broth poured over the top of commercial dry feed. This has worked well for us, but we also recognize the excellent work done by many handlers who board and "condition" dogs for the show circuit, and who swear by various combinations of herbs. We know hunters and racers who would not dream of conditioning their animals on anything but "secret" home-cooked meals. Fortunately, dogs, like humans, tolerate a wide range of food. This is the conclusion you should have come to after looking at Table 2. Multiply the Table 2 ranges by a good 40 percent individual variance and it becomes obvious that nutrition is an inexact science.

The goal of creating an intermediate reference work, somewhere between a nutritional text and a tabloid exposé, was a challenge we could not resist; furthermore, it was a goal we could not have reached without a little help from our friends. Specifically, we would like to thank Zep, who provided bulletin board services for getting text and research materials from Indiana to Oregon, and to Joe Selliken, M.D., a pathologist, who kept us going in the right direction with books and private lectures on cancers. Very special thanks go to Rene Silberman and Carol Barfield for the information on preservatives.[11,12] Closer to home, author Cargill would like to thank his little brother, Lt. Colonel W. George Cargill, USAF, for the complete download of citations on preservatives from the National Medical Database (MEDLARS). Our gratitude goes to Donna Marcel, editor of DOG WORLD, who took the gamble on our project and let us produce what is by far the longest-running series in the history of DOG WORLD Magazine. Last but not least, we appreciate the interest of DOG WORLD readers who prompted us to extend this series from four to eight articles.

References:

1. Boyd-Smith, W., "The No Barking at the Table Cookbook," Tallahassee, Fla., Erdmans, 1991.

2. Bowes, A., Church, C., "Food Values of Portions Commonly Used," 15th Ed., New York, Pennington, J., Harper Perennial, 1989.

3. Diskette DOS with Lotus 3.1 format ingredients list and recipe analysis templates is available from the

authors, c/o John Cargill, Osler Institute, 1094 E. Dawn Drive, Terre Haute, Ind. 47802.

4. Grandjean, D., Paragon, B., "Nutrition of Racing and Working Dogs, Part III," "Dehydration, Mineral and Vitamin Adaptations," and "Practical Feeding Guidelines," Compendium, February 1993; Vol. 15, No. 2: pp. 203-211.

5. Cargill, J., Thorpe-Vargas, S., "Feed that dog!, Part III," DOG WORLD Magazine, September 1993, Maclean Hunter Publishing, pp. 14-22.

6. U.S. Dept. of Agriculture, "Agriculture Handbook No. 456," "Nutritive Value of American Foods in Common Units," 1975.

7. U.S. Dept. of Agriculture, "Agriculture Handbook No. 8," "Revised, Composition of Foods, Raw, Processed, Prepared," Washington, D.C., U.S. Department of Agriculture, 1986.

8. McGinnis, T., "The Well Dog Book," "Homemade Diet for Dogs I," 1991.

9. Pitcairn, R., Pitcairn, S., "Natural Health for Dogs and Cats," Rodale Press, 1982.

10. Rosemary's Farm, Tail Waggers, P.O. Box 321 Freeland, Whidbey Island, Wash. 98249.

11. Rene Silberman, 24060 Highway 40, Golden, Colo. 80401.

12. Carol Barfield, president, United Dog Owners' Association, 3851 W. 146th St., Cleveland, Ohio 44111, petitioner in the FDA Petition Docket Number 93P0081/CPI; (216) 671-6988.

Statistician and retired Marine officer John Cargill wears many hats, among them that of an Akita breeder. He is presently involved with the Osler Institute in continuing medical education. The institute is in Terre Haute, Ind.; the Akitas live in Bonsall, Calif.

Susan Thorpe-Vargas has been accepted in the doctoral program for immunology at an Oregon university. She has an extensive chemistry and lab background and has been involved in numerous Environmental Protection Agency clean-up sites. She also raises and shows Samoyeds.

Index

AAFCO, 2, 3, 12, 15, 16, 17
Abbott's Dairies, 6
Abbrecht (1972), 8
Abiuka (1992), 21
Abnormal cell proliferation, 25
Abnormal growth, 25
Abnormal stance, 8
Abrams (1976), 3
Absorption, 10, 21, 29
Absorption rate, 6
Acclimatization, 4
Acetylcholine, 10
ACTA, 21, 24
ACTH, 22
Activation of oncogenes, 25
Additives, 9, 15, 23
Adenine triphosphate, 20, 21
Adenoma, 20
Adipose tissues, 18
ADP, 20
Adrenal gland, 28
Adrenocorticotrophic hormone, 22
Adult maintenance requirements, 4
Adverse reactions, 27
Aflotoxin B1, 26, 27
Age, 4, 5, 15, 19
Akita, 13, 15, 18, 31,
Albumin, 5
Aldehydes, 18
Alfalfa, 8, 9
Alfalfa meal, 15
Alfonsky (1954), 10
Allergic, 15, 28, 32
Allergic reactions, 28
Allergy, 8, 15, 28, 31
Allometric model, 4
Alpha cellulose, 17
Alpha tocopherols, 9, 19, 21, 22, 24
Alveolar bone, 8
American Can, 6
American Home Foods, 6
American Lecithin, 6
American Sugar Refining, 6
Amino acids, 4, 5, 6, 10, 11, 14
Anaphylactic shock, 28
Anderson et al. (1939), 9
Anemia, 8, 10, 20
Animal digest, 15
Animal fat, 15
Animal waste products, 2
Anion, 20
Anorexia, 8, 10
Antagonisms, 29
Antibiotics, 9, 10
Antibody, 10, 22, 23, 28
Antibody formation, 22
Anticarcinogen, 21
Antigen, 22, 23, 28
Antimutagenic, 27
Antioxidant, 2, 8, 9, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25,26, 27, 28, 31, 32
Anti-inflammatory, 21
Anti-oncogenes, 25
Apathy, 8
Appetite, 10, 27
Arachidonic acid, 22
Arginine, 5
Arnold, Elvehjem, Brody & Abrams, 3
Arnold & Elvehjem (1939), 4
Aromatic amino acids, 5
Arsenic, 9
Arteries, 9, 19
Arthritis, 19
Asakawa, 27
Asamoto, 27
Ascorbic acid, 9, 11, 19, 21, 27
Ash, 7, 8
Ash content, 12
Aspergillus flavus, 26, 27
Association of American Feed Control Officials, 2
Ataxia, 3
Atherogenic, 14
ATP, 20, 21
Atrophy, 20
Autoimmune disease, 28
Autoxidation, 21
Avidin, 10
Avocados, 10, 12
Azzi, 24
A-deficient, 9
A-tocopherol, 22
Bacterial, 10
Bakalova, 24
Baker's yeast, 11
Barbul et al. (1981), 5
Barfield, Carol, 21, 27, 35, 36
Barley, 14, 15, 16
Barley flour, 15
Barnett, D.V.M., 4
Barnhart, E., 11
Bartoli, 24
Baugh et al. (1971, 1975), 10
Beagle, 4, 5, 6, 8, 9, 15
Beans, 10, 32
Bedlington Terrier, 8
Beechnut, 6
Beef, 10, 12, 16
Beef material, 16
Beef (Meat), 15
Beer, 16, 18
Beet, 16
Belfied (1976), 11
Bellew, 23
Belshaw et al. (1975), 8
Beriberi, 9
Bernstein et al. (1972, 1975), 10
Beta-carotene, 18
BHA, 19, 20, 21, 24, 26, 27
BHT, 19, 20, 21, 24, 26, 27
Bieri & Evarts (1973), 9
Biester et al. (1936), 8
Bilayer, 23
Bioavailability, 14
Biochemical individuality, 14
Biologic stages of life, 9, 28, 29
Biologic value, 6, 7, 18, 28, 29, 35
Biological, 9, 12, 14, 15, 18, 20, 21, 31
Biomembranes, 24
Biotin, 10
Birth defects, 20, 22
Bitches, 5, 6, 13, 15, 22
Black tongue, 10
Blackstrap molasses, 10
Blackwell, 6
Bladder, 9, 20, 27
Bladder tumor, 26
Bladeren, 21
Blake (1992), 21
Blaza et al. (1980), 5
Blaza et al. (1985), 5
Blaza (1981), 3
Blood, 8, 9, 15, 16, 17, 20, 22, 24, 31
Blood plasma levels, 21, 22
Blood-brain barrier, 10
Blumberg, 22
Bone, 6, 8, 9, 16, 17, 22, 24, 29, 35
Bone closure defects, 22
Bone meal, 35
Bone plates, 9
Bone tissue, 29
Boscoboinik, 24
Bowes & Church, 31, 35
Bowman Dairy, 6
Bowry (1993), 21
Boyd-Smith, Wendy, 31, 35
Brain, 10, 16, 17, 21, 22, 23
Bran, 8, 10, 16, 17
Brands, 6, 12, 15
Breeder, 5, 11, 36
Breeders' complaints, 20
Breeding, 28
Breeds, 3, 4, 5, 6, 7, 8, 15, 20, 22, 28
Brewer's rice, 16, 17
Brewer's yeast, 10, 11
Brody, 3
Broth, 35
Brown rice, 16
Burke, 23
Burns et al. (1981), 5
Burns et al. (1982), 5
Butylated hydroxytoluene, 19, 27
Butylated hydroxyanisole, 19, 21, 27
Byproduct, 3, 12, 16, 17, 18
B-complex, 9, 10, 11
B-lymphocytes, 23
B-vitamins, 9
Ca, 32
Cadmium, 29
Calcification, 8
Calcium, 7, 8, 9, 10, 11, 17, 28, 29, 31, 32, 35
Calcium gluconate, 28
Calcium lactate, 28
Calcium supplementation, 10, 29, 31, 35
Calcium-phosphorus ratio, 7, 9, 10, 31, 32, 35
California Packing, 6
Caloric, 3, 4, 6, 12, 15, 18, 29, 32
Calories, 4, 29, 31, 32, 35
Campbell Soup, 6
Campbell & Phillips, (1953), 4, 5
Campbell (1962), 6
Cancer, 20, 22, 24, 25, 26, 27, 35
Cancer development, 25
Cancer suppressor genes, 26
Canned, 9, 12
Canning, 6, 10
Canning technology, 12
Carbohydrate, 4, 5, 6, 8, 9, 12, 20, 21, 29, 32, 35
Carbohydrate-free, 5
Carbon(s), 18, 21
Carbonate, 8, 17
Carcass, 16, 17
Carcass stability, 27
Carcinogen, 25, 26, 27
Carcinogenesis, 21, 25, 26, 27
Carcinogenic, 14, 25, 26, 27
Carcinogenic agent, 24
Carcinogenic effects, 24
Carcinogenic synthetics, 27
Carcinogenicity, 26, 27
Carcinomas, 24, 26
Cardiac, 10
Carnosine, 5
Carotene, 9
Carpus, 8
Carrots, 9, 10, 16
Cartilage, 8
Cascade effect, 22
Casein, 5, 16
Catalyzing, 8
Cataracts, 20
Cation, 20
Cats, 2, 12, 29, 36
Cattle, 15, 16
Cayhill (1971), 22
Cell, 10, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27
development, 25
growth, 25
Cell membrane, 9, 18, 19, 20, 21, 22, 23
Cell membrane controlled functions, 22
Cell membrane permeability, 20
Cell metabolism, 18
Cell proliferation, 20, 23
Cellular, 20, 21, 23, 25
Cellular components, 19
Cellular functions, 23
Cellular pathway, 23
Cellulose, 12, 17
Cell-mediated, 22, 23
Central nervous system, 5
Cereal, 10, 14
Cereal-based food, 14
Chain reaction, 9, 19, 21, 26
Chatelain, 24
Cheeke & Shull (1972), 19, 21
Cheese, 10, 32
Chelated, 6, 21
Chelated calcium, 28
Chemical breakdown, 18
Chemical breakdown products, 18
Chemical carcinogenesis, 26

Chemical carcinogens, 26
Chemical interaction, 27
Chemical processes, 19
Chicken, 16, 18, 26, 32, 35
Chicken broth, 35
Chicken byproduct meal, 16
Chicken leg quarters, 32
Chicken liver meal, 16
Chicken meal, 16
Chicken-based food, 14, 26
Chloride, 8
Chlorine, 8, 9, 11
Cholesterol, 5, 19, 22
Choline, 10, 11
Chondro-osseous changes, 8
Christine et al. (1971), 22
Chromium, 9
Chromosomal aberrations, 26
Chromosomal translocations, 26
Chromosome, 26
Church, C., 35
Citric acid cycle, 20
Classification of cancers, 24
Classification of tumors, 24
Clastogenic effects, 26
Clayson et al. (1993), 21
Cleft palate, 22
Clotting, 9
Coagulated, 16
Coagulum, 17
Coat, 4, 8, 20, 25
Cobalamin, 10
Cobalt, 8
Cocker Spaniel, 5
Cod liver oil, 9
Coenzyme R, 10
Cofactors, 22, 25, 29
Cold-weather, 6, 18
Collapse, 10
Collins, 23
Coma, 8, 10
Committee on Animal Nutrition, 2, 6, 11, 12
Compounds, 5, 7, 9, 11, 14, 22, 25, 26, 27
Condition, 4, 9, 10, 18, 21, 22, 28, 32, 35
Conjugates, 21
Connective tissue, 24
Container Corp., 6
Continental Can, 6
Continental Foods, 6
Control Group, 5, 6
Control mechanisms, 24
Conversion factor, 35
Convulsive seizures, 8
Cooking, 10, 16, 28
Copper, 8
Copper absorption, 29
Copper toxicosis, 8
Corn, 10, 14, 16, 32
Corn bran, 16
Corn germ meal, 16
Corn gluten, 16
Corn gluten meal, 16
Corn grits, 32
Corn Products Refining, 6
Corn syrup, 16
Cornell University, 21
Costill, D.L. (1981), 6
Costochondral junctions, 8
Cotran, 27
Cowgill (1928), 3
Cows, 32
Coyotes, 6
Co-factors, 29
Co-precipitation, 16
CP, 21, 26
CPI, 36
Cracked pearl barley, 16
Cream, 17
Cretinism, 8
Critical carcinogenic dose, 26
Crosse & Blackwell, 6
Crude fat, 12
Crude fiber, 12
Crude protein, 12, 16, 17
Cumulative effects, 24
Curd, 17
Curtis Candy, 6
Cyanocobolamin, 10
Cytochrom, 27
Cytotoxicity, 22
C-complex, 11
Dairy products, 9, 15
Davies, William 6
Davis, 6
Death, 5, 9
Deciduous teeth, 8
Decreased fertility, 20
Decreased prostaglandin synthesis, 22
Defatted, 16, 17
Deficiency, 6, 7, 8, 9, 10, 21, 22, 23, 28, 29
Deformities, 8
Degeneration, 9, 10
Degenerative lesions, 9
Degradation, 10
Dehulled, 16, 17
Dehydrated eggs, 16
Dehydrated feces, 28
Dehydration, 8, 36
Demyelination, 10
Density, 8, 21, 24, 35
Dentition, 32
Depletion, 8, 11, 18
Depressed immune response, 20
Depression, 8, 10, 20, 22, 25, 29
Developmental processes, 24
Diagnostic, 23, 28
Diaphragm, 15
Diarrhea, 15
Diatomic bond, 18
Diet(s), 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 18, 19, 20, 23, 28, 29, 31, 35, 36
Healthy Foods for Puppies and Mother Dog, 30
Healthy Powder, 30
Heidi Diet, 29
Homemade Diet for Dogs!, 34
Kidney Diet: Food for Older Dogs, 30
Maintenance Diet for Greyhounds, 34
Rosemary's Farm—Hypo-allergenic Diet, 34
Supplements for Commercial Kibble, 30
Susan's Maintenance Diet, 30
Weight-Loss Diet for Dogs, 30
Dietary, 4, 5, 7, 8, 9, 10, 11, 15, 18, 22, 23
Digest material, 15, 16, 17
Digest of beef, 16
Digest of beef byproducts, 16
Digest of poultry byproducts, 16
Digestibility, 6, 14, 15
Digestible energy, 3
Digesting, 32
Dihydrodiol epoxide, 26
Dilatation, 10
Dingle (1964), 21
Diphosphate, 20
Diplock (1971), 22
Diplock (1973), 21
Direct-acting compounds, 25
Disease, 8, 10, 11, 19, 20, 21, 24, 27, 28, 31, 32
Distemper, 10, 11
Distribution systems, 18
DNA, 8, 18, 21, 23, 25, 26
Doberman Pinscher, 31
Dogs, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20, 21, 22, 24, 26, 27, 28, 29, 31, 32, 35
Dolomite, 6, 35
Dose, 24, 26
Dose-dependent, 26
Downey et al. (1980), 4
Drackett, 6
Dried animal digest, 16
Dried kelp, 16
Dried milk protein, 16
Dried reduced lactose whey, 16
Dried whey, 16
Drug, 2, 9, 10, 11, 14, 20, 26, 28
Dry weights, 14
Dryness of skin, 8
Dullness, 8
Duodenum, 10
Dutch study, 26
Dyes, 2, 28
Dysfunction, 5
Dysplasia, 31
Dyspnea, 8
Ear, 16, 31
Early growth requirements, 4
Economic, 2, 3, 20
Egg whites, 10
Egg yolk, 9, 10
Eggs, 5, 9, 10, 16, 17, 18
Eggshell powder, 29
Electron, 9, 18, 19, 20, 21, 22
Electron transport system, 20
Electro-chemical gradient, 20
Elements, 8, 9, 11, 21, 29, 31, 35
Elvehjem, 3, 4, 8, 9, 10
Elvehjem et al. (1933, 1934), 8
Elvehjem et al. (1944), 9
Embree, 9
Emulsifier, 10
Enamel, 8
Endemic, 9, 10
Endosperm, 15, 16
Endurance, 31
Energy, 3, 4, 5, 7, 9, 11, 12, 15, 18, 20, 23
Energy intake, 9
Entrails, 16, 17
Environment, 31, 32, 35
Environmental, 21, 25, 28, 36
Environmental circumstances, 4
Environmental conditions, 6,
Environmental toxins, 25
Environmentally, 28
Enzymatic hydrolysis, 15, 16, 17, 22
Enzyme(s), 9, 14, 21, 22
Epidemic, 28, 31
Epiphyseal-metaphyseal regions, 8
Epithelium, 27
Epoxide, 26
Equations,3, 4, 6, 29
Equilibrium, 5
Equivalent-weight, 2
Erdmans, 35
Erin, 24
Erythrocytes, 21
Eskew, 23
Esophageal carcinogenesis, 26
Esophagus, 15, 27
Essential fatty acids, 4, 22
Esterone, 22
Esters, 15, 16
Ethoxyquin, 12, 14, 19, 20, 21, 22, 23, 24, 26, 27, 28
Ethoxyquin toxicity, 20
Ethoxyquin-free, 12
Eukanuba, 14
Eustigneeva, 24
Evarts, 9
Excreted, 3, 7, 14
Exercise, 7, 15, 18, 31, 32
Exhaustion, 4
Exogenous sources, 11, 31
Expense, 28, 31, 32, 35
Extract, 5, 15, 16, 17
Extrahepatic, 21
Extreme muscular activity, 6
Extremities, 9
Extruded, 12
Extruding, 16
Eyesight, 31
E. Prichard, 6
Fad literature, 11
Fads, 12, 29
Failure to thrive, 22
Fair Packaging & Labeling Act, 12
Fairburn et al. (1992), 21
Fanciers, 12, 28, 31, 32, 35
Fat, 3, 4, 5, 6, 8, 9, 10, 12, 15, 17, 18, 20, 21, 22, 23, 32, 35
Fat content, 18
Fat emulsifier, 10
Fatal toxic conditions, 29
Fatigue, 8
Fatty, 15, 16, 17, 18, 22, 29
Fatty acids, 4, 17
Fatty pigment, 9
Fat-soluble, 4, 9, 18
Fat-soluble vitamins, 9, 18
Feathers, 15, 16, 17, 28
Fecal content, 16, 17
Fecal matter, 3
Fecal output, 15
Feces, 3, 15, 28, 35
Feed, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 17, 18, 20, 22, 27, 28, 29, 31, 32, 35

Feeding, 3, 4, 5, 6, 7, 10, 11, 12, 14, 16, 18, 20, 35, 36
Feeding oatmeal, 16
Feeds, 2, 3, 6, 8, 11, 12, 18, 20, 22, 27, 35
Feed-manufacturing, 2
Feet, 16, 17, 27
Female, 12, 22, 31
Ferreira (1990), 21
Ferrous carbonate, 8
Ferrous sulfate, 8
Fertility, 12, 20, 21
Fetal reabsorption, 22
Fetuses, 22
Fiber, 12, 16, 17, 32
Fibrous plant materials, 17
Field trials, 6, 10, 15
Finch, 23
Fish, 10
Fish liver oils, 9
Fish meal, 16
Fisher (1977), 8
Flako, 6
Flavor, 16
Flavus, 26, 27
Flaxseed, 17
Flea, 14, 24
Flesh, 15, 16, 17
Flour, 6, 10, 15, 16, 17, 32
Floury, 16
Fluid, 17, 19, 21
Fluoride, 8
Fluorine, 8
Folacin, 10
Folic acid, 10
Food and Drug Administration (FDA), 2, 3, 15, 20, 21, 26, 27, 36
FDA Petition, Docket No. 93P-0081/CP1, 26
FDA Talk Paper T89-71, 26
Food, Drug and Cosmetic Act, 20
Food additives, 15
Food allergies, 28
Foods, 2, 4, 6, 7, 9, 11, 12, 14, 15, 18, 20, 21, 26, 28, 29, 31, 32, 35, 36
Food stuffs, 10, 11, 18
Food-buying, 14
Food-processing, 10
Forestomach carcinogenesis, 26, 27
Forte, 24
Fractional, 26
Fractures, 7
Free, 9, 15, 16, 17, 18, 19, 21, 22, 23, 26, 35
Free radical, 9, 14, 19, 21, 22, 23, 26
Free radical damage, 23, 26
Free radical generation, 14, 18
Free radical scavengers, 22
Freezing, 9
Frohring (1935, 1937), 9
Fromm dog food, 21
Fukushima, 27
Fu-caeae, 16
Gall bladder, 9
Gallate, 26
Gastrointestinal disturbances, 10
Gastrointestinal health, 15
Gastrointestinal motility, 15
Gastrointestinal transit time, 15
GE, 3
General Foods, 6
General Mills, 6
Genes, 20, 25, 26
Genetic, 11, 21, 25, 26, 28
Genetic coding material, 23
Genetic material, 24
Genetic miscoding errors, 26
Genetic mutation, 25
Genetic selection, 24, 28
Genetic susceptibility, 28
Genome, 26
Georgia Department of Agriculture, 3
Gerber, 6
Geriatric, 15
Gerlach, 23
German Shepherds, 5
Gestation, 7, 9, 12, 15
Gey, 24
Glands, 9, 17, 28
Gluconate, 28
Glucose, 5
Glucose transport, 21
Glucose uptake, 20
Glutathione, 20
Glutathione peroxidase, 20, 21, 22
Gluten, 14, 15, 16
Gluthathione, 21
Glyceride esters of fatty acids, 15, 16
Glycoproteins, 5, 23
Goiter, 8
Goldberger & Wheeler (1928), 10
Grains, 3, 9, 10, 14, 15, 16, 20, 26, 27, 32
Grandjean, D. & Paragon, B.M. (1993), 15, 17, 32, 35, 36
Grease, 16
Great Dane, 3, 8
Gregory (1989), 14
Greyhounds, 35
Grits, 16, 32
Groats, 16
Grocery, 12
Grootveld (1992), 21
Gross, 20, 22
Gross energy, 3
Ground corn, 16
Ground dehulled oats, 16
Ground wheat, 16
Ground whole brown rice, 16
Ground whole wheat, 16
Ground yellow corn, 16
Growing, 3, 4, 5, 9, 10, 15
Growth, 4, 7, 8, 9, 10, 11, 12, 15, 19, 24, 25, 26, 29, 35
Growth hormone, 5
Growth-regulating mechanisms, 24
Guaranteed analysis, 12
Gut, 10, 21, 35
Hagiwara, 27
Hair, 4, 8, 15, 16, 17
Hairlessness, 8
Handler (1943), 10
Hard-baked flakes, 12
Harper, 35
Harris & Embree (1963), 9
Harrison, 21
Haskell, 6
Hayes, 21
Hayes et al. (1969), 9
Hazelton Labs, 27
Hazelton study, 27
Health, 2, 4, 7, 15, 21, 29, 35, 36
Health food stores, 29
Heart, 8, 9, 10, 15
Heat, 3, 9, 10, 15, 22
Hedhammer et al. (1974), 8
Heidi Diet, 28, 29
Heinz, H.J., 6
Heinzerling, 23
Hematocrit, 5
Hemolytic anemia, 20
Hemorrhagic, 10
Hemorrhaging, 9
Henrickson (1968), 8
Hepatic, 17, 22, 26
Hepatic oxygenases, 26
Hepatitis, 10, 11
Herbs, 35
Heritable, 26
Herpes, 11
Hexoses, 21
Hydroxyanisole, 21
Hide trimmings, 17
High-carbohydrate diet, 4
High-fat diet, 4, 6
High-protein diet, 6, 10
High-quality, 6, 28
High-temperature canning, 12
Hildebrand, 27
Hill, 23
Hindquarters, 10
Hip dysplasia, 31
Hirose, 27
Histocompatibility, 23
Histodine, 5
Histogenesis, 20, 21
History, 8, 26, 35
Hoffman-LaRoche, 21
Homecooking, 31, 32, 35
Hominy, 16
Homogenous, 21
Hooves, 15, 16, 17
Hops, 16
Hormonal level, 28
Hormones, 5, 9, 18, 21, 22, 28, 29, 31
Horns, 15, 16, 17
Hunter, B.T. (1971), 6
Huskies, 15
Husks, 16
Hydrocarbon, 24
Hydrogen, 22, 26, 27
Hydrogen peroxide, 21, 22, 26
Hydrolysis, 15, 16, 17
Hydrolyzed feathers, 28
Hydroquinone, 21
Hydroxyanisole, 19, 21, 27
Hydroxytoluene, 19, 27
Hydroxy-radicals, 26
Hyperextension of the carpus, 8
Hyperplasia, 26
Hypersensitivity, 28
Hypoallergenic diet, 14
Hypothermia, 10, 21
Iams Eukanuba Original, 14
IARC, 26
Iditarod, 4
Iditarod sled dogs, 6
Immune, 9, 10, 20, 21, 22, 23, 24, 25, 26, 28
Immune regulatory system, 28
Immune response, 5, 10, 20, 22, 23
Immune system, 8, 9, 21, 22, 23, 25, 26, 28
Immunity, 23
Immunologic, 23
Immunology, 36
Immuno-competent cells, 23
Impurities, 17
Inactivation of anti-oncogenes, 25
Incisor teeth, 8
Indirect-acting compounds, 25
Indispensable amino acids, 5, 6
Individual, 4, 15, 18, 31, 32, 35
Individual variance, 31, 32
Individuality, 14
Indomethacin, 22, 23, 27
Induce, 25, 26
Induced, 10, 11, 19, 21, 25, 26, 27, 28
Inducers, 27, 28
Inducing, 26
Induction, 20, 24, 26, 27
Industrial chemicals, 24
Infected, 23, 25
Infection, 23
Infectious, 11, 20
Inflammation, 8, 10
Inflammatory, 21
Ingest, 5, 6, 23
Ingested, 4, 6, 15, 20, 23
Ingesting, 8
Ingestion, 27, 29, 31
Ingold et al. (1993), 21
Ingredients, 2, 3, 6, 8, 12, 14, 15, 17, 18, 27, 28, 31, 32, 35
Initiating carcinogens, 24
Initiation of cancer, 24
Initiators, 24, 25, 26
Inorganic, 8
Inositol, 11
Inoue, 27
Insulin, 5
Intake, 5, 7, 8, 9, 10, 11, 15, 29
Interactions, 7, 9, 10, 11, 23, 24, 27
International Association of Registered Carcinogens, 26
Intestinal, 29
Intestinal bacteria, 10
Intestinal synthesis, 10
Intestinal tract, 21
Intestine, 10, 16, 17, 21
Intracellular, 22
Iodine, 8
Ion, 9, 20
Ionic species, 20
Iron, 6, 8, 9, 11, 29
Irradiated, 9
Irreversible, 24, 26
ISBM, 6, 11
Isoleucine, 5
Ito, 27
Iverson, 21
Japanese study, 26
Jaw, 8

Jejunum, 10
Joint spaces, 19
Joints, 8, 9, 21
JPN, 27
Kade et al. (1948), 5
Kagan, 24
Kahl, 27
Karafuto dogs, 2
Kelp, 9, 11, 16
Kennel cough, 11
Kern (1981), 21
Kernel, 15, 16, 17
Ketones, 18
Kibbled corn, 16
Kidney, 8, 10, 20
Kidneys, 16, 17, 20, 22, 32
Kinase, 24
Kinetics, 26
Kleinjans, 27
Knight et al. (1992), 21
Knoll, 27
Knox gelatin, 6
Koster, 21
Kozlov, 24
Krehl & Elvehjem (1945), 10
Krehl (1945), 10
Kronfeld et al. (1977), 7
Kuf (1992), 21
Kumar, 27
Kutsky, 31
Label, 3, 12, 14, 18, 19
Labeling, 2, 11, 12, 14, 15, 18
Labeling practices, 11, 18
Labrador Retrievers, 3, 5, 11
Lactalbumin, 16
Lactate, 28
Lactating, 3, 15
Lactation, 4, 5, 7, 9, 12, 15
Lactose, 9, 16
Laetrile, 11
Lamb, 18, 26
Lamb bone meal, 16
Lamb digest, 16
Lamb fat, 16
Lamb meal, 17
Lamb-based food, 14, 26
Lameness, 8, 19
Laminaricae, 16
Lard, 10
Law of large numbers, 27
Lecithin, 6, 10
Leg, 8
Lehniger, Albert (1933), 31
Lenhart, 8
Leningrad, 12
Lesions, 8, 9, 10, 20, 22, 27
Lethal, 20
Leucine, 5
Leukemia, 24, 26
Leveque (1969), 11
Libby McNeil & Libby, 6
Life-threatening, 28
Lining, 8
Link, 22, 24
Linked, 18, 19, 21
Linoleic acid, 4, 22
Linseed meal, 17
Lipid bilayer, 23
Lipid peroxidation, 23
Lipid peroxide, 19
Lipids, 18, 19, 21, 20, 23, 24
Lipofuscin, 9
Lipoperoxide, 20
Lipoprotein(s), 19, 21, 24
Lipotropic, 10
Live births, 6
Liver, 5, 8, 9, 10, 16, 17, 20, 21, 22, 26, 27, 32
Lobbying, 14
Loew (1981), 21
Lok, 21
Long bones, 8
Longevity, 14, 24
Loss of bone, 8
Loss of hair, 8
Loss of skeletal density, 8
Low-density lipoproteins, 19
Lowry (1989), 14
Low-temperature, 16, 17
Lucy & Dingle (1964), 21
Lucy & Diplock (1973), 21, 22
Lucy (1971), 22
Lung, 16, 17, 20, 21, 26
Lymph, 24
Lymphocyte stimulation, 20
Lymphomas, 24
Lysine, 5, 14
Macauley, 22, 23
Macklin, Larry, Ph.D., 21
Magnesium, 8, 29
Major histocompatibility complex (MHC), 23
Malaise, 8
Male, 22, 27
Malformed puppies, 22
Malfunction, 24
Malkinson, A.M. (1991), 21
Malondialdehyde, 18
Malted grain, 16
Mammal tissue, 17
Mammals, 5, 6, 11, 15, 17
Manganese, 8
Manure, 17
Marine & Lenhart (1909), 8
Marketing approaches, 4
Martin (1973), 23
Martin (1992), 21
Mash, 10
Masui, 27
Material Safety Data, 20
McCormick, 6
McCoy, 5
McGinnis, 36
McLellan et al. (1992), 21
McNamara, J.H., 6, 15, 17
McNeil, 6
Meal, 5, 6, 14, 15, 16, 17, 32, 35
Measurement, 15, 18, 29, 32, 35
Meat, 2, 6, 10, 14, 15, 16, 17, 28, 32
Meat and bone meal, 17
Meat-based food, 14, 26
Medium and giant breeds, 3
Meeker, 23
Megadoses, 11
Membrane, 9, 18, 19, 20, 21, 22,23
Membrane damage, 23
Membrane lipids, 23
Membrane phospholipids, 9
Membrane-active, 26
Membrane-bound antioxidant, 19
Memory, 10
Menadione, 9
Mental disorders, 10
Metabolic, 21, 22, 25, 29
  antagonism, 29
  conversion, 25
  fade out, 20
  hormones, 5
  pathway, 21, 22, 29
  processes, 29
  products, 18
  reactions, 9
  regulation, 4
  role, 19
Metabolism, 9, 18, 21
Metabolite(s), 19, 25, 26, 27
Metabolizable, 4, 12, 15
Metabolizable Energy (ME), 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15, 20
ME caloric requirements, 4
ME caloric values, 4, 12
ME caloric values of feed ingredients, 4
ME maintenance requirements, 3
Metabolizable energy requirements, 3
Metabolized, 18, 26
Metabolizing, 19
Metacarpo-phalangeal joints, 8
Metatarso-phalangeal joints, 8
Methionine, 5, 10
Methyl, 10
Meydani et al. (1991), 22, 23
Meyer, Dan, D.V.M., 21
Mice, 21, 22, 23, 27
Microsomes, 26, 27
Middlings, 16, 17
Military working dogs, 6, 17
Milk, 7, 9, 10, 16, 17, 18, 32
Mill, 16, 17
Milled, 16
Milling, 15, 16, 17
Mindell, E. (1991), 11
Mineral (s), 6, 7, 8, 9, 11, 22, 28, 29, 31, 32, 35, 36
  antagonism, 29
  requirements, 7
  synergisms, 28, 29
  tolerance, 7
Mineralized lesions, 8
Mineral-vitamin synergisms, 3
Minimum Testing Protocol, 15
Minnesota Valley Canning, 6
Miscoding, 26
Mitochondria, 20, 21
Modulation, 21, 22
Moist foods, 12
Moisture, 9, 12, 16
Molasses, 10
Molecular structure, 19
Molecular weight, 23
Molecule(s), 18, 20, 21, 22, 23, 26
Molybdenum, 8
Monosaccharide(s), 21
Monsanto, 26, 27
Mortality, 6
Motility, 15, 22
Mottling, 8
Mucosal, 27
Multiplicative effects, 24
Muscle, 5, 8, 9, 15, 18, 22, 24
Muscle cells, 18
Muscular, 9, 20
Muscular activity, 6
Muscular paralysis, 8
Muscular weakness, 8, 20
Mush, 12, 14
Mutagen, 26, 27
Mutagen activity, 26
Mutagenic, 14, 18, 26
Mutation, 25, 26
Myocardium, 8, 9
NADPH, 21
Nafstad & Skaare, 22
National Academy of Sciences, 4, 12
National Biscuit, 6
National Dairy Products, 6
National Research Council (NRC) , 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 15, 20, 29, 31, 32, 35
  NRC-74 equation, 4
  NRC-74 standards, 31
National Sugar Refining, 6
Natural antioxidants, 19, 26
Natural killer cell, 22
Natural killer cell-mediated cytotoxicity, 22
Necrosis, 8, 10
Neoplasia, 24, 27, 28
Neoplasm, 24
Nera, 21
Nerve, 10, 15
Net utilization factor, 6
Neurological disorders, 10
Neurological functions, 5
Neurological syndromes, 9
Neuronal degeneration, 10
Neurotransmitter, 10
Newfoundlands, 3
Niacin, 10
Niacinamide, 10
Nickel, 9
Nicotinic, 10
Nitrogen balance, 5
Nitrogen equilibrium, 5
NK cells, 22, 23
NKCC, 22
Non-chelated, 6
Non-facultative, 23
Non-inflammatory, 19
Non-prescription, 10
Non-rendered, 16, 17
Non-tumorigenic, 25
Nostrand, 31
Nourishment, 12
Novikov, 24
Nutrient, 4, 6, 9, 11, 12, 14, 31, 32
Nutrient values, 31
Nutrient-to-energy ratio, 4
Nutrition, 4, 6, 7, 11, 12, 14, 17, 20, 21, 22, 27, 29, 31, 35, 36
Nutrition Foundation, 2
Nutritional content, 31
Nutritional value, 31
Nutritionists, 31
N-dibutylnitrosamine, 27
Oat groats, 16
Oats, 6, 8, 10, 15, 16
Obese, 31
Ocular lesions, 10
Offal, 17
Official Pet Food Regulations, 12
Oil, 9, 16, 17, 21, 22

Oncogene(s), 25, 26
Ontko et al. (1957), 5
Ontko & Phillips (1958), 4, 5
Ophthalmological changes, 19
Oral hygiene, 12, 22
Organ meat, 32
Organic, 11
Organism, 22, 25, 26
Organs, 5, 20, 21, 26, 32, 35
Orotic acid, 11
Overdose, 20
Over-nutrition, 8
Over-processed, 28
Owens Illinois Glass, 6
Oxidation, 9, 10, 18, 21, 22
Oxidation number, 22
Oxidative state, 22
Oxidized, 19
Oxygen, 6, 9, 18, 20, 26, 27
Oxygen capacity, 6
Oxygenases, 26
Oysters, 8
PABA, 11
Packer, 24
Packing, 6, 31
Pain, 8
Palatable, 12
Palate, 22
Pangamic acid, 11
Pantothenic, 10
Paragon, 15, 17, 32, 35, 36
Parakeratosis, 8
Paralysis, 8
Parasitized, 23
Pathogenesis of cancer, 24
Pathologic, 27
Pathological fractures, 7
Pathological reaction, 28
Pathways, 21, 22, 23, 29
Payne (1965), 3
Payne (1985), 4
Peanut, 28
Pearl barley, 16
Peas, 32
Pellagra, 10
Penicillin, 9
Penn, 23
Pennington revision, 31, 35
Pentose phosphate system, 21
Pentoses, 5
Pericarp, 17
Periodontal disease, 20
Peripheral nerves, 10
Permeability, 20
Peroxidase, 20, 21, 22
Peroxidation, 9, 21, 23, 24
Peroxide, 19, 21, 22, 26, 27
Pesticides, 24, 26, 32
Pet allergies, 28
Pet Food Institute, 12
Petition, 20, 21, 26, 37
Pets, 14, 20, 28, 29
PGE_2, 21, 22
Phenolic compounds, 26
Phenylalanine, 5
Phillips, 4, 5
PhosChol, 10
Phosphate, 21
Phospholipids, 9
Phosphorus, 7, 8, 9, 11, 28, 29, 30, 32, 35
Phosphorous salts, 8
Physiological, 4, 9, 20
Physiology, 23
Phytate, 8
Pigment, 9
Pillsbury Flour Mills, 6
Pitcairn, Richard, D.V.M., 29, 36
Plant, 3, 15, 17
Plasma, 5, 21, 22
Plecknor, Al, D.V.M., 28, 31
Point mutation, 26
Poison, 20
Polyunsaturated fatty acids, 9
Pork, 10
Postnatal mortality, 6
Post-mortem, 22
Potassium, 8
Potatoes, 5, 17
Potency, 12, 15, 35
Potent, 9, 14, 21, 26, 32
Poultry, 15, 16
Poultry byproduct meal, 17
Poultry byproducts, 17
Poultry digest, 17
Poultry fat (feed grade), 17
Powdered cellulose, 12, 17
Precancerous lesions, 20
Prednisone, 8
Pregnancy, 3, 4, 15
Premature closure of bone plates, 9
Preservative, 2, 8, 12, 15, 17, 19, 20, 23, 24, 27, 28, 32, 35
Preserved foodstuffs, 20
Prichard, 6
Prilipko, 24
Pro Balance, 4
Procarcinogens, 25
Profile Performance, 4
Prolactin, 5
Prophylactic, 11
Propyl gallate, 26
Prostaglandin, 21, 22, 23
Prostaglandin E_2 synthesis, 21, 22
Prostration, 10
Protein, 4, 5, 6, 7, 8, 9, 11, 12, 16, 17, 18, 19, 20, 23, 24, 25, 26, 28, 29, 31, 32, 35
Protein coating, 23
Prothrombin, 9
Proton, 20
Proto-oncogene, 25, 26
Psychological temperament, 4
PUFA, 9, 11
PUFA peroxidation, 9
Pulmonary adenoma histogenesis (PAH), 20
Pulp, 16, 17
Pulverized peanut hulls, 28
Puppies, 4, 5, 6, 8, 9, 10, 11, 12, 15, 20, 22, 32
Pyridoxal, 10
Pyridoxamine, 10
Quaker Oats, 6
Quality, 2, 7, 14, 15, 18, 26
RA, 9, 21
Racing, 6, 15, 17, 36
Radiation, 25, 27
Radical(s), 9, 14, 18, 19, 21, 22, 23, 26
Radioactivity, 26
Rancid fats, 9
Rancid oils, 9
Rancidity, 9, 18, 21, 22
Rations, 12, 15, 31, 35
Ratios, 4, 6, 7, 8, 9, 10, 11, 14, 31, 32, 35
Rats, 19, 21, 22, 27
Raw, 10, 36
RDA, 11
Reabsorption of fetuses, 22
Reaction, 8, 9, 19, 21, 26, 27, 28
Reactive, 18, 21, 26
Receptors, 23
Recessive, 25, 26
Recipe analysis, 35
Reconstituted, 20
Recycled animal waste products, 2
Recycling, 24
Red blood cells, 21
Red meat, 32, 25
Red Star Yeast, 6
Redox potential, 21
Refining, 6
Regenerate, 20
Regulatory processes, 24
Reinhold, 31
Relative efficacies of antioxidants, 18, 19
Relative protein requirements, 4
Rendered, 15, 16, 17
Renner, 27
Replication, 23, 25, 26
Reproductive, 23, 24, 28
  difficulties, 22
  performance, 4
  systems, 22, 23
Research colony animals, 31
Restlessness, 8
Retarded growth, 8
Retention, 5, 8
Retina, 19
Retinopathy, 19, 21
Reynolds, Arleigh, D.V.M., 21
Riboflavin, 9
Rice, 5, 10, 12, 14, 16, 32, 35
Rice bran, 17
Rice flour, 17, 32
Riis et al. (1981), 19, 21
Ritov, 24
RNA, 23, 25, 26
Robbins, 24, 27
Roche (1981), 9
Rodent, 26
Rolled oats, 16
Rose & Rice (1939), 5
Rumen, 17
Rye, 10
R-squared, 4
Safe levels, 24, 26, 27
Safeway, 6
Sakata, 27
Salt, 2, 8
Sanecki et al. (1982), 8
Santoquin, 27
Sarcomas, 24
Saunders, 27
Sawdust, 12, 17
Scent discrimination, 10
Scheuchenzubber, 23
Schilderman, 27
Scholze, 23
Schuster, 6
Schutzhund, 10
Schweighert, 4
Scita, 24
Scurvy, 11
Se, 22
Seaweed, 11, 16
Seidler & Schweighert (1954), 4
Seizures, 8
Selenide, 8, 22
Selenite, 23
Selenium, 8, 9, 11, 19, 21, 22, 23, 24, 29
Selenoprotein, 23
Self-oxidation, 9
Self-regulates, 29
Self-regulation, 11
Selliken, J.H. Jr., M.D., 35
Semi-moist foods, 12
Sensitivity, 26
Serbinova, 24
Serum, 5, 8, 21
Serum T3, 8
Serum T4, 8
Shapiro (1991), 22
Sheffy (1964), 10
Sheffy (1972), 11
Sheffy (1981), 21
Shelf-life, 18, 21, 28
Sherman et al. (1934), 8
Shibata, 27
Shirai, 27
Shull, 19, 21
Signs, 8, 9, 10, 11, 15
Silano (1986), 23
Silberman, Renee, 35, 36
Silicon, 9
Simon, 6
Sinew, 15
Skaare, Janneche, 20, 21, 22
Skeletal, 11, 15, 31, 32
  deformities, 8
  disease, 8, 31
  pain, 8
Skimmed milk, 17
Skin, 8, 9, 10, 15, 16, 17, 20, 28, 32
Skin allergies, 8
Skin eruptions, 10
Skull, 8
Slaughtered, 15, 16 ,17
Slaughterhouse, 32
Smell, 10, 18
Smith (1981), 31
Smith (January 1981), 21
Smoking, 24
Smooth muscle, 22, 24
Sodium, 11, 23
Sodium fluoride, 8
Solid Gold, 12
Sorbitol, 9
Sorghum, 32
Soups, 11
Soy, 5, 6, 8, 9, 10, 14, 15, 17, 32
Soya lecithin, 10
Soybean, 17
Spalholtz, J., 23, 31
Spalholtz, et al. (1973), 23
Spaniel, 5
Spastic, 10
Species-specific study, 27, 28
Sperm count, 22
Sperm motility, 22
Shapiro, 23
Spinach, 8
Spinal, 10

Spleen, 16, 17
Squamous cell carcinomas, 26
Standard Brands, 6
Starch, 15, 16
Sterility, 20, 22
Sterilized, 16
Steroid, 8
Stocker (1993), 21
Stoichev, 24
Stomachs, 16, 17
Stool, 6
Storychev, 24
Stouffer, 6
Stress, 6, 15, 17, 18, 28, 31, 32
Striate, 15
Subcommittee on Dog Nutrition, 6, 11
Sugar, 2, 6, 16, 18, 21, 23
Sulfa drugs, 9, 10
Sulfate, 8
Sulfur, 10
Sun-cured, 15
Sunlight, 9
Supplementation, 7, 29, 32, 35
Surface markers, 23
Swelling, 28
Symptoms, 20, 28
Synapses, 10
Syndromes, 9
Synergisms, 29
Synergistic, 8, 20
Synergistic minerals, 29
Synergistic relationships, 29
Synergists, 29
Synergy, 9, 24
Synovial fluid, 19, 21
Synthesis, 5, 8, 9, 10, 18, 21, 22, 23, 26, 29
Synthetic antioxidants, 21, 22, 23, 24, 25, 26, 27, 31
Syrup, 16
S-transferases, 21
Tables, charts, graphs and figures:
- Biologic Value of Feed Ingredients, 4
- Caloric Needs for Given Biological Stage, 29
- Canine Dietary Mineral Requirements, 7
- Canine Dietary Vitamin Requirements, 7
- Changes in Energy Requirements for a 20-kg Husky in harness, 14
- Comparison of Commonly Available Dog Foods, 13
- Ingredients commonly usedin dog foods, 33
- Limits to Vitamin & Trace Mineral Daily Intake, 32
- ME Caloric Requirements, 2, 3
- ME Caloric Values of Feed Ingredients, 4
- ME Energy and Protein Requirements, 4
- Mineral Synergisms, 28
- Nomenclature of Tumors, 25
- Nutritional Requirements by Exercise Level, 32
- Relative efficacies of antioxidants, 18
- Relative ME Energy Requirements, 14
- Safe levels of ethoxyquin, 18
- Mg/Kg Ethoxyquin Ingested Daily, 19
- Vitamin-Mineral Synergists, 28
- Vitamin Synergists, 28

Tablescraps, 31
Tagawa, 27
Tallow, 17
Tappel (1980), 9
Tatematsu, 27
TCMC, 22
Teare et al. (1980), 11
Teeth, 8, 15, 16, 17
Temperament, 4
Temperature, 4, 7
Teratogenesis, 20
Terriers, 8, 9
Tert-butyl, 21
Testes, 9
Testicular atrophy, 20
Testosterone, 22
Thermal, 16
Thermoneutral environment, 31
Thermoregulation, 15, 18
Thiamin, 9
Thickened skin, 8
Thonrley allometric equation, 4
Thonney linear equation, 4
Threonine, 5
Threonine-deficient, 5
Thyroid gland, 8, 28
Timidity, 8
Tin, 8
Tinedt et al. (1979), 8
Tissue, 5, 10, 14, 15, 16, 17, 18, 20, 23, 24, 29
Tissue-level, 14
Titchenal et al., 5
Titer, 17
Tocopherols, 9, 23, 24
Tocotrienols, 24
Tolerance, 7, 11
Tolerate, 32, 35
Tomassi & Silano (1986), 23
Tooth enamel, 8
Torula, 11
Total mineral content, 7
Toxic accumulation, 29
Toxic compounds, 14
Toxic effects, 29
Toxic levels, 26, 27
Toxic metabolites, 26, 27
Toxicity, 20, 21, 23, 26
Toxicological, 27
Toxicology, 21, 22, 23, 27
Toxicosis, 8
Toxins, 25
Trace elements, 8, 31
Tracking, 10
Translocation of genes, 26
Treadmill, 4
Triphosphate, 20, 21
Tryosine, 5
Tryptophan, 5, 10
Tsuda, 27
Tufts Center on Aging, 21
Tufts University, 22
Tumor, 21, 24, 26, 27
Tumorigenesis, 26
Tumor-suppressor genes, 25
Turkey, 17
Turkey broth, 35
Turkey leg quarters, 32
Turkey meal, 17
Turner, 23, 24
Tyrosine, 5
T-cells, 23
T-lymphocytes, 22, 23
T-lymphocyte-mediated cytotoxicity, 22, 23
Ulcerations, 8
Ultraviolet sunlight, 9
Uncoordinated gait, 8
Undecomposed animal tissue, 15, 16, 17
Under-processed, 28
United Animal Owners Association, 21, 27
United Fruit, 6
United State Department of Agriculture (USDA), 3, 32, 36
Unmilled, 10
Unoxidized, 21
Unpalatable, 21
Unpolished, 10
Unprotected, 27
Unsaponifiables, 17
Urinary, 27
Urinary bladder, 9
Urine, 3, 6, 35
Uterine inertia, 22
Uterine muscle, 22
Uterus, 9
Utilization factor, 6
Uviquinol, 21
Vaccine failure, 20
Vaccines, 26
Vacuum-packed, 12
Vahonny (1985), 15
Valine, 5
Valley, 6, 23
Van Ommen et al. (1992), 21, 31
Vanadium, 9
Vegetable(s), 9, 10, 32
- deep-green leafy vegetables, 10
- green vegetables, 9, 10
- leafy green vegetables, 9, 10

Vehegan, 27
Veins, 9
Venial, 32
Veracity, 3
Verhagen, 21
Viral relationship, 24, 25
Viral replication,23
Virus, 10, 11, 23, 25
Viscera, 16, 17
Visek et al. (1976), 6
Vitamins, 3, 4, 6, 7, 8, 9, 10, 11, 12, 14, 18, 19, 21, 22, 23, 24, 27, 28, 29, 31, 32, 35, 36
Vitamin antagonisms, 29
Vitamin requirements, 7
Vitamin-mineral, 29
Vitamin-mineral synergists, 28, 29
Vomiting, 8
Vorhees, Frank A. Jr., 20
Walling (1993), 21
Wannemacher & McCoy (1966), 5
Ward (1992), 21
Water balance, 8
Water intake, 8
Waterfowl, 23
Watery, 17, 23
Water-soluble, 10, 11
Water-soluble vitamins, 9
Weakness, 8, 9, 10, 20
Wean, 4, 12, 15
Webster et al. (1966), 8
Weight, 3, 4, 7, 8, 9, 10, 11, 12, 14, 15, 18, 23, 29, 31, 32, 35
Weight-loss, 9, 15, 29
Weston, 6
Wet weights, 14
Wheat, 6, 8, 9, 10, 14, 16, 32
- bran, 17
- flour, 17
- germ, 10
- germ meal, 17
- middlings, 16
- mill run, 16, 17
- shorts, 16, 17

Wheeler, 10
Whelped, 5
Whelping, 15
Whey, 11, 16, 17
Whidbey, 36
Williams (1992), 21
Winyard (1992), 21
Worksheet, 29, 35
Wort, 16
Wysong, Randy, D.V.M., 14
Zarkower, 23
Zinc, 8, 29
Zinc absorption, 29
Zinsmaster, 6
Zucker, M. (1933), 31